MEMOIRS

OF THE

GEOLOGICAL SURVEY

OF

INDIA.

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INDIA.

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TO THE

Memory

OF

FERDINAND STOLICZKA, Ph.D.,

Formerly PALÆONTOLOGIST to the Geological Survey of India,

Who lost his life in the discharge of his duty, on the return journey of the Second Mission to Yárkand,

June 19th, 1874, at the age of 36 years,

THE FOLLOWING WORK,

On the GEOLOGY of the COUNTRY with which HIS NAME will ever be ASSOCIATED,

IS DEDICATED

BY

THE AUTHOR.

PREFACE.

—:o:—

In the following memoir I have endeavoured as much as possible to confine myself to the actual description of the geology of the countries of which it treats, and to the consideration of such hypotheses and inferences as are absolutely necessary to a right understanding of the relations of the different formations. The bearing of the facts recorded on the wider question of the origin of the Himalaya, and of other mountain systems, has been in the main left for those physicists who have made such subjects their especial study. The geographical and topographical notices have been made as brief as possible, their sole object being to enable the reader to easily comprehend the geological descriptions. Much the same may be said of the notice of the physical features of the country.

I may perhaps be allowed to avail myself of the privileges of a preface to notice one or two points which might have been alluded to in the text, although as not being necessary to the comprehension of the geology, are more in place here. These will be best understood after a perusal of the memoir itself.

It may be observed that the inner limit of the region of the Outer Hills[1] does not exactly correspond with this boundary as given by Mr. Drew. According to Mr. Drew[2] this boundary commences on the Rávi some ten miles north of Basoli, then runs just north of the towns of Rámnagar, Riási, and Rájáori, and thence in a less definable course towards Muzafarábád. In another passage,[3] however, Mr. Drew is less clear as to this northern boundary, since he speaks of it as being "less defined [than the southern boundary]: in some parts a line of mountains from 8,000 to

[1] *Infra*. p. 5. [2] "Jummoo and Káshmír Territories," p. 96. [3] *Ibid.*, p. 27.

10,000 feet high, ends it off; in others, tracts having the characteristics of the Outer Hills penetrate in between the mountains; in others still these characters gradually shade off, so that one cannot point out exactly where they may be said to end." At all events for geological purposes, it is far better to follow the course adopted in the text, and make the northern boundary of the Outer Hills coincident with that of the Sub-Himalayan tertiary system.

It will of course follow from the above that the southern boundary of the region of the "Middle Mountains" runs more to the north than in Mr. Drew's classification, according to which the Panjál range forms the northern limit of this region, while in this memoir it is included in it. This region in any case is a purely artificial one, but it is of considerable convenience. In the description of the physical features of the two regions given in the text[1] it will be understood that near their junction the features of the one region pass gradually into those of the other.

A word may perhaps be expected as to the term "Alluvial System," employed in the fourth chapter. It was found advisable to adopt some general comprehensive name for the more or less superficial formations, which at the same time should not confine them to any one geological period. On these grounds the term "alluvial system" was adopted, using the word alluvial in a wider sense than usual, and as applicable to any superficial deposit. A purely topographical name would undoubtedly have been better, but it did not seem that there was one suitable. If it should eventually be proved that the lowest karewas of the Káshmír valley are the same as the highest Siwaliks of the Outer Hills it will only lead to the conclusion that in the former region there is no well-marked break between the "Tertiary" and the

1 *Infra.* pp. 22-4.

"Alluvial Systems," although a very decided one exists in the latter region.

Since the whole of the text was in type, I have seen the number of the "Records" containing Col. Mc'Mahon's paper on the microscopic structure of the Dalhousie rocks (of which I had previously only seen the proof-sheets), and I observe it is suggested[1] that the term "central gneiss" should in future be dropped; while it is concluded that at least many of the granitoid rocks of the Dhauladhâr are of tertiary age, and were erupted at the time of the origin of the Himalaya. The latter conclusion is in perfect accord with the views expressed in the IXth chapter (although I had not ventured to say that the eruption of the granitic rocks was as late as the tertiary period), but I still see no reason for dropping the terms "central" and archæan gneiss, as I think it is proved that crystalline rocks existed at the time of the deposition of the older palæozoics, and that it is always with these rocks that the eruptive rocks of the Dhauladhâr, and their probable equivalents in other districts, are associated. I may add that the term "hypogene," used in connection with these rocks in the text is employed in the original sense of *underlying*, as opposed to *overlying*.

Since the greater part of the memoir was printed it has occurred to me that the contortions in the lacustrine beds of Skárdu noticed on page 71 may possibly, if these beds were deposited during some part of the glacial period, have been caused by the liquefaction of interstratified masses of ice, as is considered by Sir C. Lyell to have been the case with some of the contorted drift of the Norfolk coast.[2]

Throughout this memoir I have still adhered to the old plan of employing the term "series" as more extensive than

1 "Records," Vol. XVI., p. 143.
2 See "Antiquity of Man," 3rd ed., p. 2:0, *et. seq.*

"group," as it seems so opposed to our English usage to make the latter embrace the former, according to the recommendation of the Bologna congress. In regard to the geological colours employed on the map it has been found best to retain those previously employed, as the mode of applying the proposed international scale to the formations of India has not yet been definitely settled.

In conclusion I desire to express my obligations to Mr. Drew, and to Cols. Godwin Austin and Mc'Mahon, for many valuable notes with which they have furnished me. My thanks are likewise due to the Council of the Geological Society of London for permission to use electrotypes of the woodcuts illustrative of the 'fans' of Ladákh; to Colonel H. C. B. Tanner for the permission to copy (in plate I.) his picture of the Gurez valley; to Mrs. Bridges, authoress of the "Journal of a Lady's Travels Round the World,"[1] and to Mr. Murray, the publisher, for the woodcut of the Wardwán valley (fig. 9).

Lastly, but not leastly, I have also the pleasant duty of tendering my best thanks to the Officials of his Highness the Máhârâja of Kâshmír and Jamu, and to Col. Henderson, C.S.I., and Mr. F. Henvey, C.S.I., late Officers on Special Duty in Káshmír, for the very cordial assistance which they have at all times afforded me in carrying out my official duties in Káshmír territory.

RICHARD LYDEKKER.

THE LODGE,
HARPENDEN,
HERTFORDSHIRE,—*July*, 1883.

[1] London, 1883.

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CORRIGENDA AND ADDENDA.

—:o:—

Page 10, line 11 from top, for 1810 read 1804.

„ 10, „ 1 „ bottom, for *erroneosly* read *erroneously*.

„ 32, „ 12 „ „ „ *Humbolt* „ *Humboldt*.

„ 36, „ 6 „ „ „ *gness* „ *gneiss*.

„ 69, „ 11 „ „ „ *ontlet* „ *outlet*.

„ 82, „ 12 „ „ „ *high* „ *higher*.

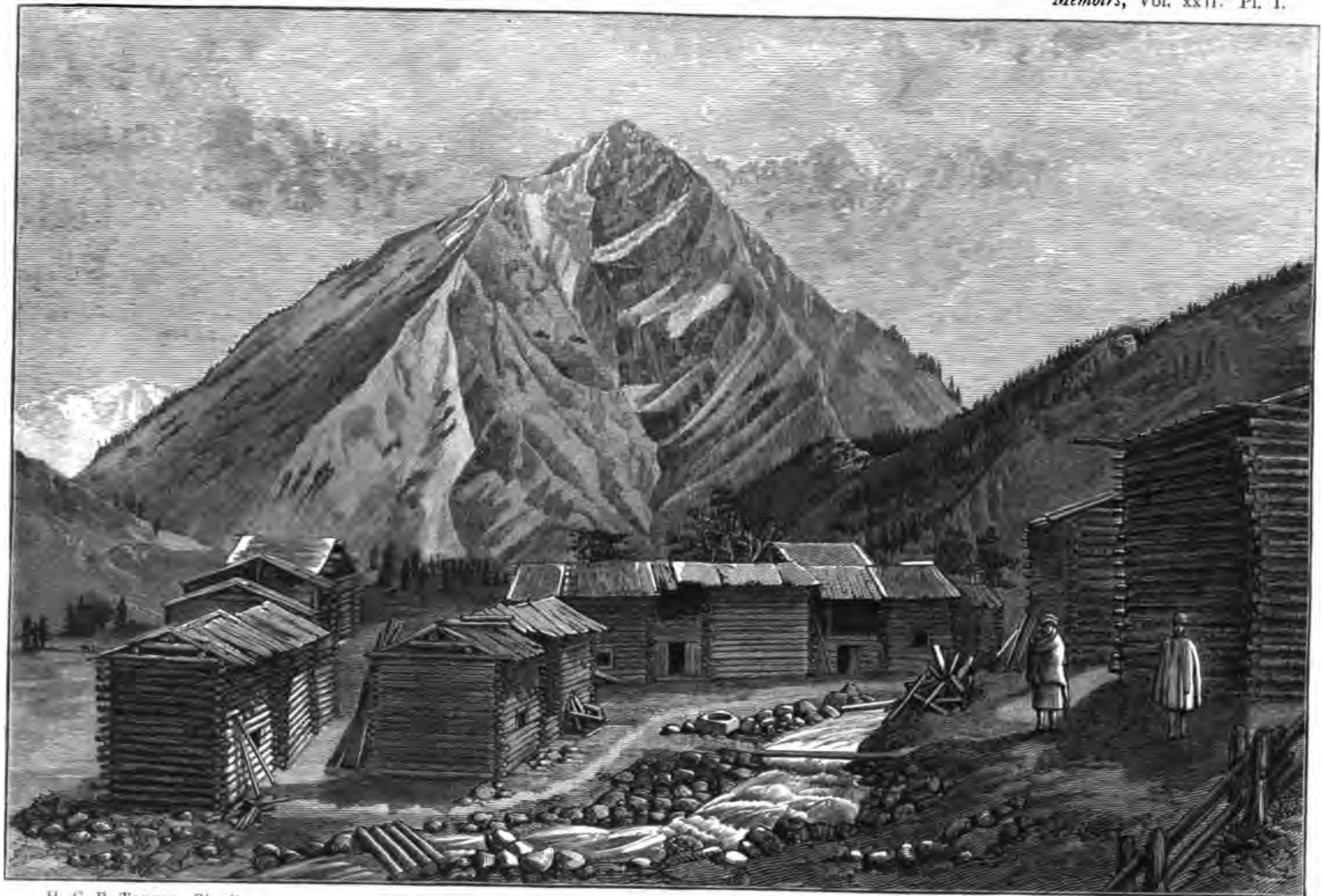
„ 94, „ 3 „ „ „ *prefatory* „ *prefaratory*.

„ 122, „ 3 „ top, „ *systems* „ *series*.

„ 161, To the numbers of the species of Káshmír Kuling fossils common to the mountain-limestone add No. 55, making the number of species common to the two formations eighteen, in place of seventeen.

„ 231, line 11 from bottom, } for *blueish* read *bluish*.
„ 237, „ 3 „ top, }

„ 323, „ 14 „ „ „ *Másemik* „ *Másimik*.



H. C. B. TANNER, *Pinxit.* H. P. WOODWARD, *Scripsit.*

THE GÚREZ VALLEY.

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THE GEOLOGY OF THE KÁSHMÍR AND CHAMBA TERRITORIES, AND THE BRITISH DISTRICT OF KHÁGÁN.—*By* RICHARD LYDEKKER, B.A., (*Cantab*): F.G.S.; F.Z.S.: *Late Geological Survey of India.*

CHAPTER I.—INTRODUCTORY.

Introductory observations; Limits of area described: General description of country; Previous geological writers.

Introductory observations.

The geological facts recorded in the present memoir are to a great extent the combined results of the work of seven long seasons spent by the writer in the examination of the rocks of Káshmír and the neighbouring regions. Much assistance has, however, been derived from the writings of other geologists, among whom the late Dr. A. M. Verchére, Lt.-Colonel H. H. Godwin Austen, F.R.S., Lt.-Colonel C. A. Mc'Mahon, and the late Dr. Ferdinand Stoliczka, are the most prominent. The latter may, indeed, be termed the founder of anything like a systematic geology of the Western Himalaya, and his untimely loss will be long regretted, both by the Geological Survey of India, and the geological world at large. Had his life been prolonged, it is probable that both the work of which the present memoir is a record, as well as the memoir itself, would have been undertaken by him, and the present writer cannot but feel how far more perfectly both would then have been executed.

The greater portion of the work described here has been already recorded in various papers in the "Records" of the Geological Survey, which will be quoted in the sequel. Since, however, the work of one season has frequently caused modifications of the views entertained at the close of a preceding season, the earlier of those papers contain many conclusions which have been subsequently superceded. On these grounds, coupled with the advantage of having a complete record of all the observations in one memoir, it has been thought advisable to combine the contents of all the earlier papers in a more amplified, and better arranged form in a single memoir.[1]

It must not, however, be considered that the present memoir has any pretence to be a complete and detailed account of the geology of the regions of which it treats. It must, on the other hand, be regarded rather in the light of a foundation, or a stepping-stone, from whence future more detailed work may take its rise. The country of which the geology is described is, indeed, in many cases, of such an arduous and inhospitable nature, that (although this is not the place for recording the hardships and difficulties against which the Himalayan geologist has to contend) it is in many cases impossible to study the geology of many of the more interesting districts with the precision that might be wished. Moreover the very vastness of the area which is provisionally geologically coloured in the map accompanying this memoir, will of itself explain that its geology is but superficially examined, since a detailed examination in place of taking seven, would be more likely to take seventy summers. In many instances it will be found that the sections are examined much more closely along the main lines of road, near which the geological boundaries

1 As this memoir contains nearly all the information given in those papers, and is intended to supercede them, it is of course unnecessary to cite them as authorities for description.

on the map may be taken to be fairly accurately laid down, while farther away from these roads the lines are more or less approximately drawn. In the geological examination of the higher Himalaya, indeed, almost the only practicable method of procedure is to take numerous transverse sections across the strike of the rocks along the chief roads and tracks, and then to join in the boundaries of the different formations from these data. In the less elevated regions of the middle and outer districts, like the Káshmír valley, and in the elevated, though more open, ground of upper Ladákh it is, however, frequently possible to follow the geological boundaries directly across the country, and in those parts it has been practicable to map them with a fair approach to accuracy.

A word is necessary as to the use of one or two native words which will occur frequently in the sequel. The first of these is the Tibetan word '*Tso*' which originally means water, and subsequently a lake, and in the latter sense is frequently used in combination, as in Tso-Moriri; it would of course be highly improper to add to this and similar compounds the English word 'lake.' Similarly the word '*Lá*' is the Tibetan equivalent for the English word pass (coll), and, therefore, when compounds like the name Zoji-lá are employed, they do not need the addition of the word 'pass.' Again, the word for a lake in Káshmíri is either '*nág*' or '*sár*,' and when either of these terms are employed it would of course be superfluous to add their English equivalents. The word *nalla* (*nullah*) which is occasionally used in the sequel, means a ravine or valley.

The map accompanying this memoir is a geologically coloured reproduction of the one accompanying Mr. F. Drew's "Jummoo and Káshmír Territories," of which Messrs. Stanford had the copyright.[1]

1 It was found advisable to omit the mountain shading, as this interfered with the geological colouring.

In the text the names of places have generally been spelt in accordance with the spelling on this map, and it will, therefore, not unfrequently happen that some of these names are not spelt in this memoir in the same way that they were spelt in the preliminary memoirs. In cases where this discrepancy is very marked the old spelling is given in brackets, at the first time of using a name.

Limits of area described.

The area of which the geology is described in the present memoir comprehends the whole of the dominions of the Máharája of Káshmír and Jamu, the Kárákoram range being taken as the boundary on the north-eastern frontier; the Chamba state, and a small angle of the British district of Láhol (Lahool); and, on the extreme west, the British district of Khágán. The whole of this area may be roughly estimated at about 68,000 square miles.

General description of country.

Numerous works have been written on the geography of the country under consideration, Mr. F. Drew's great work—"The Jummoo and Káshmír Territories,"[1] being perhaps the most important: from this work the following summary of the chief divisions of the country is mainly compiled. Much valuable information is, however, contained in the works of Messrs. Cunningham, Moorcroft, Thompson, Vigne, and others, which are cited in the sequel. Mr. Andrew Wilson's "The Abode of Snow,"[2] and Major J. Biddulph's "The Tribes of the Hindoo Khoosh,"[3] also give valuable descriptions of some of the wilder districts, and of the difficulties of traversing them.

The first point to which attention should be directed is the application of the name 'Káshmír.' There is no doubt that this term should properly be confined to the basin of the upper Jhelam; since, however, it is frequently extremely convenient to have a general term

1 London, 1875. 2 Edinburgh and London, 1875. 3 Calcutta, 1880.

to comprehend the whole of the numerous districts owning allegiance to the Káshmír Government, the term Káshmír, or Káshmír Territory, will in the sequel be generally employed in this wide sense; Káshmír proper being designated as the Káshmír Valley.

The south-westerly portion of the country defined above includes a small strip of the plains of the Punjab, beyond which the outermost ridges of the Himalaya commence. These outer ridges have been termed by Mr. Drew the 'Outer Hills,' a name which will frequently be adopted here, though the term Sub-Himalaya will also be employed in the same sense. This tract is taken to include all the area south of the Káshmír valley which is coloured various shades of brown in the map, and is coincident with the Sub-Himalayan, or tertiary, rock-series. It includes the districts of Púnch (Poonch), Naoshahra (Naoshera), and Jamu (Jumoo), in the last of which is situated the town of Jamu, the capital of the whole Káshmír territory. Through this tract the rivers Jhelam, Chínáb, and Rávi, make their way to the plains of the Punjab. Although the 'Outer Hills' continue along the whole of the foot of the Himalaya, the river Rávi nearly forms the boundary of those coming within the area under consideration.

On the inner side of the Outer Hills is the tract to which Mr. Drew has given the name of the 'Middle Mountains.' It comprises, to the north-west, the range of mountains running from the Kishanganga valley at the east of Muzafarábád (Mozufferabad) to the Chínáb, known as the Káj-nág range to the north-west of the Jhelam, and as the Pír-Panjál to the south-east, though the latter term is not unfrequently applied to the whole range. To the south-east of the Chínáb, in the districts of Kishtwár and Bhadarwáh (Badrawár) the 'Middle Mountains' are continued, though as a less well-defined range, to the Rávi, beyond which they again form the well-marked Dhauladhár

range, forming the outer barrier of Chamba. The 'Middle Mountains' are considered by Mr. Drew to comprehend the whole of the Kishtwár and Bhadarwáh districts.

For the purposes of the present memoir a short enumeration of the chief river systems, and mountain ranges of the rest of the country, will be sufficient to clear the way for the right comprehension of its geology.

Commencing at the north-western extremity, there is the valley of the Kúnhár (Koonhar)[1] river, which falls into the Jhelam a short distance below its great bend at Muzafarábád, and the upper part of which forms the British district of Khágán,—a narrow strip of Hazára: the north-westerly boundary of this valley forms the Indus watershed, beyond which lies the inaccessible district of Chilás. At Muzafarábád the Kishanganga river joins the Jhelam, after flowing through the districts of Shárdi, Gurez (Gurais), and Tilel (Tilail), and taking its origin in the mountains to the westward of Drás. In its lower course the western boundary of the Kishanganga valley forms the eastern boundary of Khágán, while higher up it forms the outer boundary of the Indus basin. The main road to the northern part of Káshmír territory passes through Gurez. The Jhelam itself, after a short course through the Outer Hills above Muzafarábád, cuts directly through the Pír-Panjál range in a narrow gorge, terminating at Uri (Ooree) and Báramúla, and its upper basin forms the valley of Káshmír proper. The southern boundary of the Káshmír valley is formed by the Pír-Panjál range; while its northerly boundary is formed by an extension of the great chain of mountains which to the south-east separates the basins of the Chínáb and the Indus, and will be here known as the 'Zánskár range.' The chief tributaries of the Jhelam in the Káshmír valley are the

1 Sometimes known as the Nainsúkh.

Sind and the Lidar rivers, both flowing from the glaciers of the great northern range. The high-road from Sirínagar, the capital of Káshmír proper, to Ladákh follows the course of the former river.

The next great river-system is that of the Chínáb, which leaves the Outer Hills at Akhnúr, after a tortuous course through the Middle Mountains from Kishtwár; at the latter point it is joined by the Wardwan river, flowing through the Máru-Wardwan valley, to the east of Káshmír proper, from the mountains to the south of Drás. Above Kishtwár the Chínáb, or Chandra-Bágha as it is there frequently called, flows through the districts of Pádar and Pángi, (the latter belonging to the Chamba state), and takes its origin in the separate rivers of the Chandra and Bhága in the British district of Láhol. The lofty mountain chain forming the northern boundary of the Chínáb valley, and separating it from the Indus, is here termed, as already mentioned, the "Zánskár range."

By far the largest river-system of the whole area is that of the Indus, which leaves Káshmír territory in the district of Astor, where it receives the Astor river flowing from the Kishanganga watershed, and along the course of which the Astor and Gilgit road proceeds from Gurez. Above Bowanji (Boonji) the Indus receives the Gilgit river, flowing from the town and district of that name, which form the extreme north-western limit of Káshmír territory. The districts of Gilgit, Astor, Gurez, and Tilel, are collectively termed Dárdistán, from a peculiar Aryan race, the Dards, who inhabit them. Above Gilgit the Indus makes a sharp bend to the south-east and flows through Rondu from Skárdu,[1] the capital of Baltistán,[2] or Little Tibet. At this point it receives a large tributary flowing from the

1 Iskardo, Skardo, or Kardo, according to the Tibetan custom of clipping off more or fewer of the initial vowels and sybilants of words.

2 The 'home of the Baltis,' a mahamedanized Tibetan race.

north, and taking its origin in the mighty glaciers of the Mustágh or Kárákoram range north of Baltistán, known as the Shigar[1] river. A little above Skárdu the Indus receives its great tributary the Sháyok (Shyok), which is really the larger stream of the two. The Sháyok flows through the districts of Chorbat and Nubra, and in its upper course receives the drainage of the Lingzhíthang and Dipsang plains, and the southern side of this part of the great Mustágh or Kárákoram range: it also drains the Chángchenmo valley, on the frontier of Chinese Tibet, and the regions about the Pángkong lake. The Indus above its junction with the Sháyok is separated by the lofty plateau of Deosai (12,000 feet) from the basin of the Kishanganga: above Kártákso it receives the drainage of the united Drás and Suru (Sooroo) rivers, flowing through Kargil, and draining the north-western boundaries of the Káshmír and Wardwan valleys. Above its junction with the Drás-Suru river, the Indus flows through Ladákh, the road from Káshmír to Leh joining its valley at Khalsi (Kalse, Kalchi, or Kalatse), and the Zánskár river flowing in some distance below the capital town of Leh. The latter river drains the district of the same name, which is a mountain-locked valley to the north of the Zánskár range, already mentioned. The range forming the northern boundary of the Indus valley in Ladákh, will here be termed the 'Ladákh range,' although it is sometimes known as the Kailás range. The range forming the southern boundary of the Indus valley in the same district will be termed the 'Kanri range,' so named from Kanri peak,[2] opposite the town of Leh, its highest point. Beyond Leh the Indus continues in a south-westerly course up to the boundary of Káshmír territory, receiving a part of the drainage of the elevated plateau of

1 This must not be confounded with the river of the same name draining the plateau of Deosai.

2 This peak is not marked on the accompanying map.

Rupshu (Rupsu or Rukshu), a district occupying the space between the Indus on the north, and the British districts of Láhol and Spiti on the south. The last great river basin is that of the upper Rávi, which comprises the chief part of the Chamba state, although to the latter also belongs the district of Pángi, in the Chínáb valley. The Rávi leaves the hills at Basaoli, above which it skirts the northern end of the Dhauladhár range, its gorge then opening out into the wide Chamba valley. The northern and easterly boundaries of the latter form the watershed of the Chínáb and Sutlej basins.

Previous geological writers.

The original notices and memoirs relating to the geology of the area under consideration are very numerous, and scattered through various publications, so that it is difficult to form a complete list. In the following list, all the more important of these notices are cited, and in most cases a brief *resumè* of their purport is given: the papers of the present writer are, however, still more briefly cited, as their contents are embodied in this memoir. In addition to the notices of the geology of the country forming the subject of the present memoir, there are numerous notices and memoirs relating to the adjacent portions of the Himalaya, which have a certain bearing on the present subject, and many of which will be quoted in the sequel; it has not, however, been thought advisable to mention the greater number of these memoirs in the following list, though a few of the more important are cited. In cases where the notice, or memoir, treats mainly of country beyond the limits of the area under consideration, an asterisk is prefixed to its title. The notices are arranged in chronological order, and in citing their purport it is necessary to forestall, to a certain extent, the information contained in the sequel.

1837-8. HUGH FALCONER. "OFFICIAL REPORT *of* EXPEDITION *to* CASHMERE *and* LITTLE TIBET *in* 1837-38." "*Palæontological Memoirs of Hugh Falconer*," vol. I., p. 557. Gives occasional remarks on the geology of the districts traversed on the route from Káshmír to Skárdu. A note on page 567 of the volume quoted indicates that Dr. Falconer determined the existence of carboniferous limestone in the Káshmír valley. In another note on the same page reference is made to a peculiar heating of the ground in the same district, described as having reduced soft alluvial strata to the condition of a well-burnt brick. About 1810 the ground is stated to have been so hot that rice could be boiled by digging down a few inches.

1840. C. F. VON HÜGEL. "KASCHMIR *und das* REICH *der* SIEK." Stuttgart. Vol. II. The alluvial formations of the Káshmír valley are alluded to (p. 82), and the conclusion arrived at that the valley was once occupied by a vast lake, which was subsequently drained by changes of level, the frequency of earthquakes being considered as confirmatory of this view. On page 242 the mineral products of the valley are noticed, and stated to comprise iron, lead, copper, limestone, and (on the Pír-Panjál) graphite. The occurrence of sulphurous springs is also recorded, but dry sulphur is stated to be unknown.

1841. W. MOORCROFT. "TRAVELS *in the* HIMALAYAN PROVINCES, *etc.*" London. Occasional notices, very frequently erroneous, are given of the rocks of Káshmír and Ladákh.

1842. G. T. VIGNE. "TRAVELS *in* KASHMIR, LADAK, ISKARDO, *etc.*" London. Occasional observations are recorded on the rocks of the above-mentioned countries. Nummulites are erroneosly

(1842.) stated to occur in the limestones of the Káshmír valley. The mountains around Siríngar (vol. II., p. 60) are described as consisting of amygdaloidal trap, which is the first correct determination of that rock.

1852. T. THOMSON. "WESTERN HIMALAYA *and* TIBET." London. In this volume many geological observations of considerable interest are recorded. The lacustrine strata of the Káshmír valley, Ladákh, and Skárdu are discussed at some length, and it is suggested that those of the latter place may have been crushed up and contorted by the action of ice. The conglomerates of the tertiaries of the Indus valley in Ladákh are recorded to contain gneiss pebbles, and the igneous origin of the associated traps is also indicated. The amygdaloids around Sirínagar are likewise considered to be of igneous origin. Dr. Thomson brought back nummulites, stated to have been obtained from the Singhe-lá, on the road from Zánskár to the Indus, which were afterwards determined by Messrs. D'Archiac and Haime to be *Nummulites raymondi*.

1853. D'ARCHIAC *and* HAIME. "*Description des* ANIMAUX FOSSILES *du* GROUPE NUMMULITIQUE *de* L'INDE, *etc.*" Paris. Contains a notice of *Nummulites raymondi* brought from Ladákh by Dr. Thomson. Other specimens are recorded from "the province of Káshmír," but it is probable that they also came from Ladákh.

1854. A. CUNNINGHAM "LADAK, *Physical, Statistical, and Historical; with* NOTICES *of the* SURROUNDING COUNTRIES." London. Occasional notices are given of the rocks in different parts of Ladákh and Baltistán, and (pl. V.) a map of the ancient lake system of Ladákh, as indicated by the occurrence of

(1854.) lacustrine deposits. From the occurrence in these lacustrine strata at higher elevations of existing shells which are not found living above 11,000 feet, it is inferred that the climate of Ladákh was once considerably milder and moister than at present, permitting the presence of forms of animal life at much higher elevations.

1856. S. P. WOODWARD. "*On the* LAND *and* FRESHWATER SHELLS *of* KASHMIR *and* TIBET, *collected by* DR. T. THOMSON." '*Pro. Zool. Soc.*,' 1856, p. 185.

1864. H. H. GODWIN AUSTEN. "*The* GLACIERS *of the* MUSTAKH RANGE (*Trans-Indus*)." '*Pro. Roy. Geog. Soc.*,' vol. viii., p. 35. Describes the large glaciers of upper Baltistán, and adduces evidence showing that they were formerly much more extensive.

H. H. GODWIN AUSTEN. "GEOLOGICAL NOTES *on part of the* NORTH-WESTERN HIMALAYAS; *with* NOTES *on the* FOSSILS *by* T. DAVIDSON, R. ETHERIDGE, *and* S. P. WOODWARD." '*Quar. Jour. Geol. Soc.*,' vol. XX., p. 383. Describes (1st) the fluvio-lacustrine series of the Káshmír valley and Baltistán; (2nd) the Siwalik series of the Outer Hills; (3rd) the [so-called] Nummulitic [really secondary] series of the outer Pír-Panjál; (4th) the jurassic series of Zánskár; (5th) the carboniferous of the Káshmír valley; and (6th) the older rocks of these districts. The carboniferous fossils described are all from the Káshmír valley, and not, as stated, from Shigar, in Baltistán. A list of terrestial shells is given from the lacustrine deposits.

H. B. MEDLICOTT. "*On the* GEOLOGICAL STRUCTURE *and* RELATIONS *of the* HIMALAYAN RANGE *between the rivers* GANGES *and*

(1864.) RAVI." '*Mem. Geol. Sur. Ind.*,' vol. III. An important memoir on the geology of the Outer Hills and adjacent regions mainly to the eastward of the country forming the subject of the present memoir, but embracing its south-eastern angle. The rocks were divided into two great divisions the 'Sub-Himalayan,' comprising the tertiaries, and the 'Himalayan' comprising all the older rocks. The older rocks were for the first time divided into distinct successional groups, indicated by local names, but not identified with European geological horizons. Some of the views expressed as to the relations of the upper tertiaries have been modified in later papers by the same author.

1865. F. STOLICZKA. "GEOLOGICAL SECTIONS *across the* HIMALAYAN MOUNTAINS, *from* WANGTU-BRIDGE *on the river* SUTLEJ *to* SUNGDO *on the* INDUS: *with an account of the* FORMATIONS *in* SPITI, *accompanied by a Revision of all known Fossils from that District.*" '*Mem. Geol. Sur. Ind.*,' vol. V., pt. I. A most important memoir, illustrated with coloured sections, and divided into three parts. The first part treats of the rocks of the Spiti district, lying to the eastward of the area treated of in the present memoir, but of great importance in connection with it. Fossils were found in most of the rocks, and the whole rock-series was named and classified, and correlated with European geological horizons. The oldest Himalayan gneiss was here termed the 'central gneiss.' In the second part the rocks of Rupshu, belonging to the area treated of in the present memoir, were correlated with those of Spiti. The noncrystalline rocks of the upper Indus valley were incorrectly determined. The third part is devoted to a discussion as to the relative age of the rocks of

(1865.) other districts of the Himalaya, and a provisional identification of Mr. Medlicott's rock-groups with those of Spiti is given. The memoir is also illustrated by numerous plates of fossils.

F. R. MALLET. "*On the* GYPSUM *of* LOWER SPITI, *with a list of* MINERALS *collected in the* HIMALAYAS, 1864." '*Mem. Geol. Sur. Ind.*,' vol. V. p. 154. Records minerals found in the Púga mines of the upper Indus valley.

1866. H. H. GODWIN AUSTEN. "*On the* CARBONIFEROUS ROCKS *of the valley of* KASHMERE; *with notes on the* BRACHIOPODA *by* T. DAVIDSON." '*Quar. Jour. Geol. Soc.*,' vol. XXII., p. 29. Describes detailed sections, with illustrations, of the rocks of the Káshmír valley, which are classed as carboniferous and lower palæozoic, the igneous origin of some of the latter not being recognised. The memoir is illustrated with two plates of Brachiopoda, all of which, belonging to the carboniferous, were obtained from the Káshmír valley, and not, as stated, from Tibet.

A. M. VERCHÉRE. "KASHMIR, *the* WESTERN HIMALAYA, *and the* AFGHAN MOUNTAINS, *a geological paper, etc.*" '*Jour. As. Soc. Ben.*,' vol. XXXV., pp. 89, 159. Shows that the so-called nummulites obtained in the Káshmír valley by Messrs. Vigne and Flemming were crinoid stems. The author considers that the tertiary 'Murree beds' are crushed against the older rocks of the Káj-nág range and that the peaks of the latter are composed of porphyry (granite), probably of igneous origin. The lower part of the Káshmír limestone series is classed as of carboniferous age, and is shown to rest on amygdaloidal and slaty rocks, some of which are considered to be lavas, others trap-ashes more or less altered,

(1866.) and others again unaltered detrital sedimentaries. The higher beds of the limestone series, for which the name Kothair is proposed, are considered to be possibly of triassic age. The trap is considered to have altered the limestones of part of the Káshmír valley, and is accordingly regarded as intrusive and of post-carboniferous age.

F. STOLICZKA. "*Summary of* GEOLOGICAL OBSERVATIONS *during a visit to the* PROVINCES, *etc.*, *of* WESTERN TIBET." '*Mem. Geol. Sur. Ind.*,' vol. V., pt. III. This paper was "intended only as preparatory to a more detailed report on the geology of the N. W. Himalaya,"—a purpose which, through the untimely death of the talented author, was never fulfilled. It treats of the geology of Láhol, Ladákh, Zánskár, Suru, Drás, and the Káshmír valley. The tertiary age of the non-crystallines of the upper Indus valley was determined; triassic fossils were obtained in Ladákh and in the upper Sind valley of Káshmír; and the rocks underlying the carboniferous of the Káshmír valley were considered to be probably altered silurians, their igneous origin not being clearly admitted.

1871-2. H. *von* SCHLAGINTWEIT-SAKUNLUNSKI. "Reisen *in* Indien *und* Hochasien." Jena. Vols. II. and III. Occasional remarks are given on the rocks of the Káshmír valley and Ladákh, but no important identifications are made.

1873. F. DREW. "ALLUVIAL *and* LACUSTRINE DEPOSITS *and* GLACIAL RECORDS *of the* UPPER INDUS BASIN." Part I. Alluvial Deposits.[1] '*Quar. Jour. Geol. Soc.*' vol. XXIX. p. 441. A general description of the above-mentioned deposits, which will be largely quoted in the sequel.

[1] The second part of this memoir has never been published.

(1873.) G. HENDERSON. "LAHORE *to* YARKAND." London. Some notes on the geology of the country between Leh and Yárkand, with two sections, are given. The photograph facing page 45 gives a good idea of the appearance of the tertiaries of the upper Indus valley; the rocks in the south-east angle being traps, and those further in on the same side the sedimentaries. Alluvial terraces are well displayed on the left, and gneiss mountains in the distance. Figure 1 in the plate facing page 50 shows the volcanic rocks, and the metamorphic shales of the palæozoic series in the gorge leading from Lámayúrú to the Indus in Ladákh. In figure 2 of the same plate the tertiaries of Khalsi, on the Indus, are well exhibited in the back-ground.

1874. F. STOLICZKA. "*A brief account of the* GEOLOGICAL STRUCTURE *of the* HILL RANGES *between the* INDUS VALLEY *in* LADAK, *and* SHAH-I-DULA *on the* FRONTIER *of* YARKAND TERRITORY." '*Rec. Geol. Surv. Ind.*,' vol. VII. p. 12. The observations recorded here are republished in Mr. W. T. Blanford's work quoted below.

1875. F. DREW. "*The* JUMOO *and* KASHMIR TERRITORIES." London. A geographical account of these countries containing occasional references to their geology, and a chapter on the alluvial formations, and the later geological history of the Káshmír valley.

H. W. BELLEW. "KASHMIR *and* KASHGAR." London. Contains a few observations on the geology of the route from Káshmír to Yárkand.

1876. R. LYDEKKER. "NOTES *on the* GEOLOGY *of the* PIR-PANJAL, *and* NEIGHBOURING DISTRICTS." '*Rec. Geol. Surv. Ind.*,' vol.

(1876.) IX., p. 155. Treats chiefly of the rocks of the Outer Hills, and describes two sections across the main range into Káshmír: shows that the so-called nummulitics of the Pír-Panjál range are of pre-tertiary age. The paper is illustrated by a map, and a section across the Pír-Panjál range: the amygdaloids of the latter district are suggested to be of non-igneous origin.

H. B. MEDLICOTT "NOTE *upon the* SUB-HIMALAYAN SERIES *in the* JAMU (*Jummoo*) HILLS." *'Rec. Geol. Surv. Ind.'* vol. IX., p. 49. Treats mainly of the tertiaries of the Outer Hills.

1877. * C. A. MC'MAHON. "*The* BLAINI GROUP *and the* 'CENTRAL GNEISS' *in the* SIMLA HIMALAYAS." *'Rec. Geol. Surv. Ind.,'* vol. X., p. 204. This paper treats of rocks beyond the area described in the present memoir, but has some important observations regarding the relations of several of the rock-groups, and the denudation of the 'central gneiss.'

1878. W. T. BLANFORD. "SCIENTIFIC RESULTS *of the* SECOND YARKAND MISSION — GEOLOGY." Calcutta. A compilation from the notes, maps, and specimens of Dr. Stoliczka, made and collected during his journey from Murree, through Káshmír, to Yárkand in 1873-4. It treats of the geology of the route, — *viz.* of Murree, the Jhelam valley and Káshmír proper, Ladákh, the Chángchenmo valley, and the Kárákoram route.

R LYDEKKER. "NOTES *on the* GEOLOGY *of* KÁSHMÍR, KISHTWAR *and* PANGI." *'Rec. Geol. Surv. Ind.,'* vol. XI., p. 30. Treats of the geology of the districts named, and is illustrated

(1878.) with a map. The Káshmír amygdaloids are inferred to be of volcanic origin, and the existence of gneiss belonging to two distinct ages is indicated.

1879. R. LYDEKKER. "GEOLOGY *of* KÁSHMÍR (*3rd notice*)." '*Rec. Geol. Surv. Ind.*,' vol. XII., p. 15. Treats mainly of the mesozoic ellipse of Sonámarg and the upper Kishanganga valley, and is illustrated by a small map. A notice of the old glaciation of the Káshmír valley is appended.

* C. A. MC'MAHON. "NOTES *of a tour through* HANGRANG *and* SPITI." '*Rec. Geol. Surv. Ind.*,' vol. XII., p. 57. The rocks treated of in this paper are all beyond the area under consideration, but comprehend the same formations.

P. M. DUNCAN. "SCIENTIFIC RESULTS *of the* SECOND YARKAND Mission. — SYRINGOSPHÆRIDÆ." Calcutta. An illustrated description of certain Zoantharian fossils obtained from the lower mesozoic rocks of the Kárákoram.

1880. H. H. GODWIN AUSTEN. "*On the* POST-TERTIARY *and* MORE RECENT DEPOSITS *of* KASHMIR, *and the upper* INDUS *valley*." '*Brit. Assoc. Rep.*,' 1880, p. 589. In this paper the lacustrine strata on the north side of the Pír-Panjál (Hirpúr series) are referred to the pleistocene. The karewas of Káshmír are divided into the older Islámábád, and the newer Báramúla group. It is inferred that the upper Indus valley was once like what the Pángkong lake now is; and that the coarse gravels of Múlbeck and Khárbu, in Ladákh, are older than the fine silt of Lámayúru, and that they bear the same relations to the latter as the gravels of Chángchenmo do to the lacustrine beds of the Pángkong lake. It is considered

(1880). probable that glaciers may have descended into the valley of the Jhelam from the Káj-nág range; and that the general absence of glacial markings in the Himalaya is no proof of the absence of former glaciation, as the rate of denudation has probably been greater than in Europe.

R. LYDEKKER. "GEOLOGY *of* LADÁK *and* NEIGHBOURING DISTRICTS, *being 4th notice of the Geology of Káshmír* and *neighbouring Territories.*" '*Rec. Geol. Surv. Ind.*,' vol. XIII., p. 26. This paper, illustrated by a map, treats of the geology of the country on and adjoining the main road from Káshmír to Leh, of a considerable portion of Drás, Zánskár, and Ladákh; the regions about the Pángkong lake and Chángchenmo, and a part of Rupshu and Kulu.

* C. L. GRIESBACH. "PALÆONTOLOGICAL NOTES *on the* LOWER TRIAS *of the* HIMALAYAS." '*Rec. Geol. Surv. Ind.*,' vol. XIII., p. 94. This paper, although treating of rocks beyond the area under consideration, yet has some observations regarding the age of rock-groups within that area.

1881. C. A. MC'MAHON. "NOTE *on the* SECTION *from* DALHOUSIE *to* PANGI viâ *the* SACH PASS." '*Rec. Geol. Surv. Ind.*,' vol. XIV., p. 305. Describes the section of the gneiss, palæozoics, and newer rocks across the Chamba state. The conglomerate in the slate series is correlated with the Blaini conglomerate of Simla, and considered to be probably of upper silurian age. Traces of a former glaciation of the Pángi valley are noticed.

F. R. MALLET. "*On* OLIGOCLASE-GRANITE *at* WÁNGTU *on the* SUTLEJ, NORTH-WEST HIMALAYAS." '*Rec. Geol. Surv. Ind.*,'

(1881.) vol. XIV., p. 238. Shows that the intrusive granite veins of the north-western Himalaya contain oligoclase, and not, as was previously supposed, albite felspar.

R. LYDEKKER. "GEOLOGY *of part of* DÁRDISTÁN, BALTISTÁN, *and* NEIGHBOURING DISTRICTS, *etc.*" '*Rec. Geol. Surv. Ind.*,' vol. XIV. p. 1. Gives map and sections of the above-mentioned districts, with a general description of their geology. Gneiss belonging to two geological epochs is described, sometimes penetrated by intrusive granite. The limestone rocks of the Káshmír valley are more closely examined, and shown to be in part of triassic age. The paper concludes with a notice of the ancient and modern glaciation of Baltistán, and of the thermal springs of the same district.

1882. R. LYDEKKER. "GEOLOGY *of* NORTH-WEST KÁSHMÍR *and* KHÁGÁN, etc." '*Rec. Geol. Surv. Ind.*,' vol. XV., p. 14. A paper, illustrated with a map and section, describing the geology of a great part of the Kishanganga and Khágán valleys; various errors connected with the north-westerly termination of the sub-Himalayan tertiaries are corrected.

C. A. MC'MAHON. "*The* GEOLOGY *of* DALHOUSIE, NORTH-WEST HIMALAYA." '*Rec. Geol. Surv. Ind.*,' vol. XV., p. 34. An important paper illustrated with a map. The amygdaloidal rocks of this district and Káshmír are considered to be certainly of volcanic origin: the relations of the older palæozoics to the 'central gneiss' are discussed, and the conclusion arrived at that the metamorphism of the latter is in great measure due to the intrusion of true granite. An old glacial moraine is described at the end of the paper.

(1882.) F. R. MALLETT. "*On* SAPPHIRES *recently discovered in the* NORTH-WESTERN HIMALAYA." '*Rec. Geol. Surv. Ind.*,' vol. XV., p. 138. Records that sapphires have been obtained north of the Zánskár range, probably from Padam in Zánskár. Some specimens are described.

A. B. WYNNE. "*Further* NOTE *on the* CONNEXION *between the* HAZARA *and the* KASHMIR SERIES." '*Rec. Geol. Surv. Ind.*,' vol. XV., p. 164. Gives a summary of the views entertained as to the correlation of the rock-groups of the districts mentioned.

O. FEISTMANTEL. 'NOTE *on remains of* PALM LEAVES *from the* (TERTIARY) MURREE *and* KASAULI BEDS *in India*." '*Rec. Geol. Surv. Ind.*,' vol. XV., p. 51. A portion of a palm leaf obtained from near Chakoti, in the Jhelam valley, is referred to *Sabal major* of Heer,—a characteristic European miocene species.

T. and R. D. OLDHAM. "*The* THERMAL SPRINGS *of* INDIA." '*Mem. Geol. Surv. Ind.*,' vol. XIX., pt. 2. Catalogues the thermal springs of the country.

1883. C. A. MC'MAHON. "*Some Notes on the* GEOLOGY *of* CHAMBA." '*Rec. Geol. Surv. Ind.*,' vol. XVI., p. 35. Describes the continuation of the rocks of the Chamba valley towards Bhadarwáh.

Chapter II.—PHYSICAL FEATURES.

Characters of mountains: climate: lakes: river valleys: caverns: glaciation: evidences of igneous action.

Characters of Mountains.

For a full account of the chief orographical features of the country the reader may consult Mr. Drew's work, and it will accordingly suffice for the purpose of the present memoir to record very briefly a few of the more striking of these features, the notice of which has been largely drawn from that work. Taking the district in the neighbourhood of the Chínáb valley as a typical one, it will be found that on leaving the plains of the Punjab, whose geological features will not be discussed in this memoir, the mountains are found commencing along a definite line in a ridge some 1,000 to 2,000 feet above the level of the plain, which is itself about 1,000 feet above the sea-level. "Next comes a tract of rugged country, which includes various ridges running nearly parallel to the first one, with long narrow valleys between them. These ridges are 3,000 and 4,000 feet high, while the valleys have commonly a level of near 2,000 feet." This Outer Hill region is partly covered by low pine-forest and other scrub, and partly consists of bare clay, conglomerate, or sandstone rock. In climate it is much the same as the Punjab, but the heat of the summer in the narrow gorges and ravines is, if possible, more intense. Generally the outermost ridge of the Himalaya rises with a gentle and even slope of some 3° till it reaches a height of some 3,000 feet above the sea: at the crest of the ridge there is a steep escarpement of several hundred feet in height, on the side away from the plains. The ridges and valleys within

this outer ridge vary in height, depth, and width to a great extent, but generally present a very regular north-west and south-east direction, co-incident with the strike of the strata. Wide open longitudinal valleys, having the same general direction, are of frequent occurrence, and in the more easterly Himalaya are termed 'dúns' (dhoons).

The north-westerly and south-easterly strike of the rocks, which is a feature so characteristic of the Outer Hills, is maintained, though frequently in a less well marked degree, throughout the whole Himalayan system, till near the north-westerly border of the country under consideration, at which point there is a gradual sweep round of the strike, Muzafárabád being a kind of centre, till it attains a south-south-west and north-north-east direction. This bending round of the direction of the strike, of the mountain ranges, and the river-valleys, may be taken as an indication that this line is the true end of the Himalayan system, and is, therefore, taken as the boundary of the country described here.

The dúns, or longitudinal valleys, of the Outer Hills, which are not found in the neighbourhood of the Jhelam, seem to be represented by similar valleys within the main mountain ranges, Káshmír itself being apparently a large example, and numerous smaller instances occurring on the northern flanks of the Pír-Panjál range.

It will be observed that besides the great bend of the strike of all the rocks round the valley of the Jhelam at Muzafárabád, there is a corresponding minor flexure of the strike of the rocks and the direction of the ridges of part of the Outer Hills in the Chínáb valley above Akhnúr: this feature is one of considerable importance in regard to the age of the river valleys, and will be further alluded to in the

sequel. In the Outer Hills the bottoms of the river valleys are frequently flat and wide, and while the drainage lines of the minor streams are coincident with the strike of the rocks, those of the larger rivers very frequently cut more or less directly across the strike of the rocks, and the direction of the ridges.

In the region of the Middle Mountains the country consists of a mass of mountains cut into by deep ravines, or divided by more important but still narrow valleys, with hardly one wide flat space, whether plateau or valley-bottom. Its elevation is in general between 4,000 and 12,000 feet; some few valleys reach below, and some peaks rise above those limits.

"The form of the mountains bears a great contrast to that of the Outer Hills. These were shown to be ridges more or less parallel, separated by flat valleys, sometimes narrow, sometimes wide, with the main lines of drainage cutting across, that is, through the ridges. On the other hand, the Middle Mountains are ridges of varying, irregular direction, that branch again and again, like the twigs of a tree; the chief ridges are at the same time the more important watersheds.

"Looking from a geological point of view, we may say that there is not the same correspondence between the direction of the ridges and the strike of the beds as there is in the Outer Hills."

The steepness of the Middle Mountains and the narrowness of their river gorges, is a very striking feature of this region, and in strong contrast with the mountains of the interior where the valleys are more open, and the mountain sides generally less steep. In the Pír-Panjál range it may be noticed that the mountains usually present a steep escarpment towards the plains, and a long gentle slope towards

the interior. This feature, common to the Outer Hills and the Middle Mountains, is of course due to the generally inward dip of the strata. To it, in combination with other causes, may perhaps be due in part the presence of a thick vegetation, in so many parts of the Himalaya, on the northern slopes, and the complete barreness of the southern sides of the hills. The elevation of the Middle Mountains is sufficient to allow of a temperate vegetation, which attains a luxurious growth from the abundant rainfall.

Within the Middle Mountains there are more lofty mountain ranges, rising to the regions of perpetual snow. In the Zánskár range the peaks vary from 15,000 to 21,000 feet in height, and in parts peaks reaching to 20,000 feet, and upwards, are not uncommon. Beyond this range and its offshoots, forming the northern barrier of the Káshmír valley, the country, with the exception of the deep gorge of the middle Indus, is all at a great elevation. "Here the mountain ranges are of heights from 17,000 up to 24,000 feet and more; one peak (which yet is unnamed [K.2.] though the second highest known in the world) has an altitude of 28,265 feet. The valleys of this region vary much in character; in the south-eastern part are high-level flat valleys, [*e. g.* Chángchenmo] from one mile to five or six in width, at elevations of 14,000 and 15,000 feet; from that, as one goes north-westward, their height descends, the space at the same time narrowing, lofty mountains always bounding them, ultimately to as low as 5,000 feet above the sea [in the neighbourhood of Gilgit]; at the lower levels are also sometimes widenings of the valley-bottoms.

"In a few places; there are flat spaces surrounded by mountains, too wide to be called valleys." The most remarkable is the Deosai plateau at an elevation of 12,000 or 13,000 feet, and Lingzhítang and Dipsang at about 16,000 above the sea level. A very common

structural feature in many parts of the Himalaya is that in the valleys the strata are frequently nearly vertical, and highly contorted, while in ascending their bordering mountains the angle of the dip gradually diminishes, and on the crests of the hills the strata are nearly horizontal. It has been suggested from this feature that a considerable amount of the contortions occurring in the strata has taken place since the present hills and valleys were marked out.

Climate.

The rainfall steadily diminishes from the abundant fall which occurs in the region of the Outer Hills and Middle Mountains, to the almost total absence of rain in the districts of Ladákh[1] and Gilgit: in the latter regions from the absence of the necessary moisture the hills are almost entirely bare of vegetation, and there is never any forest. About Astor and in part of Baltistán the climate is intermediate between that of Káshmír proper and Tibet: here forest is to be found on the higher grounds, where a greater rainfall takes place than in the deep valleys. From the dryness of the air and practical absence of rain the climate of the Tibetan regions is one of fierce extremes, and in marked contrast to the mild and genial climate with which the valley of Káshmír is favoured. In the deep gorge of the Indus at Gilgit the fierce untempered rays of the sun beating down on the bare gneiss rocks and sand produce an almost insupportable heat, even worse than the fiery blaze of the Punjab. On the high plateau of Rupshu the summer temperature by day is excessive, but at night-fall rapidly sinks many degrees below the freezing point. The practical absence of rain in the Tibetan region conduces to the accumulation of vast quantities of detrital material, as will be noticed in

[1] It seems that the rainfall of Leh is increasing as rain for the last few years has fallen every summer, whereas in previous years it was frequently entirely absent. Many old mud-covered buildings in the town have been washed away by the unusual amount of rain.

the sequel, and is highly favourable to the preservation of many geological formations which in other regions would long since have entirely disappeared through the action of climatal agencies. The alternation of intense heat and cold in the more elevated regions, it need scarcely be observed, is highly conducive to the rapid decomposition of the rocks.

Lakes.

In common with other parts of the Himalaya, the country under consideration, with some remarkable exceptions, is noticeable for the almost total absence of lakes of any size, while such small ones as do occur, are mainly confined to comparatively high levels, not far removed from the region of existing glaciers, or where glaciers existed in comparatively recent times. At these higher levels (10,000 feet and upwards) small lakes are of not uncommon occurrence, and numbers of them occur in the high mountain barrier to the north of the Káshmír valley, though most of them are of too small a size to be represented on the map accompanying this memoir. A large collection of these small lakes, or tarns, is seen clustering around the peak of Haramuk,[1] (16,000 feet,) which forms such a conspicuous feature of the mountain barrier to the north of the Walar (Wular) lake, in the Káshmír valley. Another well-known lake is the sacred Shísha-Nág,[2] at the head of the Lidar valley, in Káshmír. Numerous small lakes are dotted over the Deosai and Rupshu plateaus. Most of these small lakes around the Káshmír valley lie in true rock basins, although, sometimes as in the case of Shísha-Nág their present rim is partly built up by detrital matter. Sum-Sár, in

1 It is curious to observe how the classic belief in the highest peaks being the abode of the Deity, prevails in these regions. Thus the name Haramuk means the 'face of God'; Diyamír, the Astor name of the peak of Nanga-Parbat (the bare mountain) on the Indus, means the 'abode of the Gods'; while Haramosh, a trans-Indus peak in Gilgit, has the same meaning as Haramuk.

2 *i.e.* The-mirror-lake.

the Pír-Panjál is, according to Mr. Drew,[1] a true rock-basin. Konsar-Nág in the same range is contained in a rock-basin nearly two miles long. The only large lakes are those of the Káshmír valley, of which the Walar is the most important; Tso-Moriri (Tsomoriri,) in Rupshu; and the Pángkong and Pangúr lakes, on the eastern frontier of Ladákh, which are only outliers of an extensive chain of lakes extending into Chinese Tibet. Both Tso-Moriri and the Pángkong lakes are considered by Mr. Drew[2] to be formed in the lines of old river drainage by means of dams of detrital material; and both were formerly much more extensive than at present. There is, moreover, abundant evidence of the former prevalence of extensive lakes throughout Ladákh, but none of these seem to have been formed in true rock-basins.

There is considerable difficulty in arriving at any satisfactory conclusion as to the nature of the basins of the lakes of the Káshmír valley since they are now deeply covered by alluvium. The small lake at Mánas-Bal has, however, a depth of nearly fifty feet, the bottom being alluvium, and seeing the small fall in the river level between this place, and its exit from the valley through the rocky gorge at Báramúla, it is not impossible that the real bottom of the Mánas-Bal basin is below the level of the rock-gorge at Báramúla, from which it might at first be inferred that the former is a true rock-basin. It will, however, be shown in the sequel that the real rock-entrance to the Káshmír valley is blocked by alluvium, so that the level of its base is unknown, and, therefore, the rock-basin theory cannot be proved. No inference can be drawn from the general absence of lakes at lower levels as to the non-existence of a former glaciation of the country, as it will be shown below that denudating agencies have obliterated most of the traces of the glacial period.

1 "Jummoo and Káshmír Territories," p. 202.
2 *Ibid* pp. 302, 323.

River valleys.

A few observations may be recorded on some of the features of the river valleys. It has been observed by Mr. Drew that many of the great rivers, after running for a long distance along the normal strike of the rocks, suddenly make a sharp bend to the south and flow more or less directly across the strike for the rest of their course; and in these cases a large tributary forms the upward continuation of the new course. This is exemplified in the bend of the Indus near the junction of the Gilgit river, and of the Chínáb at the junction of the Wardwan river above Kishtwár, and again at the junction of the Ans river above Riási, in the Outer Hills. The bend of the Jhelam at its junction with the Kishanganga, at Muzafárabád, presents an analogous feature, but here the strike of the rocks changes at the same time as the course of the river, the former being probably the cause of the latter.

Many of the rivers follow on or near to geological boundaries, as in the instances of the upper part of the Ans river, the Cháng-chenmo, the upper Indus, and the Jhelam between Uri and Muzafárabád. It is not improbable that in many instances the direction of the valleys has been induced by lines of geological weakness which may have given rise to fractures which the rivers have taken advantage of and enlarged, as it is otherwise difficult to account for the preference of the neighbourhood of these boundary lines. In the Outer Hills as already said the minor river valleys in many cases follow the direction of the strike, but most of the larger rivers, and especially the Rávi, the Chínáb, and the Ans river, have cut their valleys directly across it. The case of the Chínáb at its junction with the Ans river above Riási is a very remarkable one, as it has here cut directly through a high ridge of hard mesozoic limestone, which now stands far above the level of the surrounding tertiary rocks. In this instance it is

clearly proved, as shown in the "Manual,"[1] that the river mnst have cut its own channel entirely without any adventitious aid. Similarly the Púnch river in the Outer Hills has cut through the edge of an inlier of old limestone in the tertiary rocks; and the two Tavi streams, in the same district, have cut directly across synclinal axes. Some of the minor streams in this district have likewise cut clefts through opposing barriers of old limestone.[2] It seems, therefore, that while in some cases rivers may have followed the lines of original geological weakness, in other cases it is certain that they have been totally independent of any such inducements to the formation of channels.

By far the deepest of all the river valleys is that of the Indus below Bowanji, in Gilgit. Between that place and the Dárel district,[3] which has hitherto only been traversed by native explorers, the writer is informed by Lt.-Colonel H. C. B. Tanner, of the Survey of India, that the river flows in a narrow gorge, bordered by vast precipices ranging up to 20,000 feet in height, at a level of a little over 3,000 feet; thus making the river gorge nearly 17,000 feet in depth. That a great part of this tremendous gorge has been cut by the river itself is proved by the occurrence of river gravels, and honey-combed rock-surfaces many hundreds of feet above the present river level. The occurrence of eocene strata in the upper Indus valley would seem to indicate that, at all events part, of that valley existed in eocene times, and that an arm of the sea then occupied part of Ladákh. There is, however, no absolute proof that the lower part of the valley then existed, as it is inferred that the drainage of the upper valley then flowed in the opposite direction to its present one. Even

1 Pt. II., p. 667. 2 "Records," vol. IX., p. 53.

3 It may be noticed that in the accompanying map the course of the Indus through Chilás, Dárel, etc., is only conjecturally given. Although the course of the river has been subsequently more correctly mapped, it was unnecessary for the purposes of the present memoir to correct the original plate of the map.

in this case, however, it is probable that the lower valley also existed, and that the upper and lower parts were joined by the cutting back of their heads. If both parts of the valley existed in pre-eocene times, it is possible that the present enormous gorge may have been cut by the unaided work of the river, and the present upper Indus valley may probably be considered as a partial recutting of the old pre-eocene valley More will be added on the antiquity of the river valleys in the sequel.

A remarkable feature along the Indus valley in Dárel, for the notice of which the writer is also indebted to Lt.-Colonel Tanner, is that almost all the peaks over a considerable area, reach to a nearly uniform height of about 21,000 feet; thus apparently leading to the conclusion that this level indicates an old plain of marine denudation, originally bordered by higher ground of which the peaks of Nanga-Parbat, and Ráki-Poshi, reaching to over 26,000 and 25,000 feet are remnants. It is, at all events, difficult to give any other solution of the phenomenon.

Caverns.

The only caverns of any size known to the writer occur in the limestone rocks of the lower Lidar valley of Káshmír, about a mile above the village of Bawan. One of these has its opening about 40 feet above the ground and may be traversed for a length of about 210 feet but seems to extend much farther. The entrance to the second is nearly 100 feet above the ground, and the cavern itself is about 48 feet in length. A thick coating of stalagmite forms the floor of these caverns, and it is to be hoped that this may some day be penetrated; since, however, the caverns are in the possession of Fakírs it will be difficult to obtain the necessary permission.

Glaciation.

The present distribution of glaciers in the Káshmír and Chamba territories is admirably displayed in the larger map accompanying Mr. Drew's work.[1] It will be seen from that map that with the exception of a few small ones to the south of the Chínáb in Chamba, there are no glaciers in the region of the Middle Mountains, or of the Outer Hills. On the Zánskár range glaciers are, however, abundant, though not attaining any great dimensions. At the north-western end of this range, where it becomes lower, glaciers are absent, reappearing again on the same line in the high regions about the peak of Nanga-Parbat. One of the glaciers at the foot of that mountain, near the village of Társhing, descends to a level which is estimated at 9,400 feet, the lowest level of any existing north Himalayan glacier. To the north of the great Zánskár range glaciers do not occur in any force till the Mustágh or Kárákoram range is reached, which forms the watershed between the Indus and the Turkistán river systems. The southern side of this stupendous mountain barrier, which contains the second highest known peak in the world (K.2.), is covered with a complete network of glaciers, some of which (the Biafo and Bráldu glaciers) are only exceeded in size by the great Humbolt glacier of Greenland. These glaciers have already been fully described by Messrs. Godwin Austen, and Drew, in the memoirs cited above, and accordingly only their more striking features will be noticed here. The lowest limit to which these glaciers reach seems to be about 10,000 feet above the sea level, and, in contrast to other parts of Káshmír territory, they descend quite into the cultivated ground, their terminal moraines being frequently covered with a thick growth of cypress.[2] The Tapsa glacier

[1] As already mentioned, this map is the same as the one accompanying this memoir, but the colouring of the glaciers cannot be shewn in company with geological colours.

[2] See "Records," vol. XIV., p. 43, *et seq.*

in this district seems now to be receding, as is evinced by old grass-covered terminal moraines in front of it; while the neighbouring Palma [1] glacier is steadily advancing over its present terminal moraine which it has nearly swallowed up. The absence of any great number of deep crevasses in these glaciers is very striking, in consequence of which it is quite possible to march directly up them without the aid of ropes or axes.

Although the existing north Himalayan glaciers only in one instance descend below a level of 10,000 feet, and only very exceptionally reach that level, yet there are abundant evidences, which will now be briefly noticed, that they formerly extended to a much lower level.

It cannot be said that there are any incontrovertible proofs that glaciers ever descended to the level of the plains of the Punjab, or to the lower ranges of the Outer Hills. Large transported blocks have, however, been observed in various parts of those regions, whose position is such that it is difficult to imagine how it was attained without the aid of the transporting power of ice. At a somewhat higher elevation,—probably something over 4,000 feet—larger accumulations of gneissic boulders derived from the summits of the Káj-nág range are found in the Jhelam valley between Uri and the Báramúla gorge. These boulders are rounded and occur in a semi-stratified deposit. In the opinion of Col. Godwin Austen[2] these boulders are considered to be certainly of glacial origin, an opinion which was not formerly shared by the present writer. The great size of these boulders, and their number, coupled with circumstances to be mentioned in the sequel, does seem, however, on the whole, to render it probable that ice has had some share in their transport, but whether

1 The name is given as Punmah on the accompanying map, but is pronounced by the natives as spelt here.

2 'Brit. Assoc. Rep.,' *op. cit.*

glaciers ever descended to the level of the Jhelam itself may still be considered an open question. In any case, it is pretty evident that the final arrangement of the deposit in which these boulders occur was accomplished by river action, but river ice may have had a share in the transport of the boulders down the valley. In the valley of Káshmír itself Mr. Drew[1] thinks that "a very fine impalpable buff sand" occurring among the alluvial deposits is glacier-mud, which, if correctly determined, would indicate the former existence of glaciers in the valley, at a level of some 5,000 feet. By the late Prof. Leith Adams[2] some of the gravels at Báramúla were considered to be of glacial origin, but it is very doubtful if this view can be maintained.

Leaving these more or less doubtful instances, cases may now be noticed where there is no question of the validity of the evidence. On the Pír-Panjál range Mr. Drew[3] has recorded that at heights where mountain tarns are numerous there are abundant and unequivocal signs of former glaciation,—both in the form of rock-groovings and polishings, moraines, and scratched stones. On the Káshmír side of the range the numerous small valleys running parallel with the strike of the rocks, and known by the local name of *margs*, are generally surrounded by rounded masses of detrital matter, which, in the opinion of the present writer, are unquestionably of glacial origin. These moraines are well exhibited at the summer station of Gúlmarg, and extend downwards to an elevation of about 7,000 feet. In the Sind valley, on the north side of the Káshmír valley, Mr. Drew has observed a well-marked *roche moutonnèe* near the village of Kúlan, at an elevation of about 6,500 feet above the sea level, or 1,500 above Sirínagar. Other similar

1 "Jummoo and Kashmir Territories," p. 209.
2 "Wanderings of a Naturalist in India," p. 171.
3 *Op. cit.*, p. 203.

traces of extinct glaciers have been observed near the same place; while higher up the Sind valley, at and in the neighbourhood of the summer station of Sonámarg, at an elevation of some 9,000 feet, there are undulating valleys which are entirely made up of old moraines. Small glaciers are now found at Sonámarg at a level of some 2,000 feet above these old moraines. Crossing the water-shed at the head of the Sind valley by the Zoji-lá into the district of Drás, near the fort at the latter place, at an elevation of some 10,000 feet, there exist huge embankments of detrital matter, some four or five miles in length, extending from the crystalline ridges on the north into the Drás valley, and consisting in great part of boulders of crystalline rocks, and resting on the slates of the valley. It is probable that ice has had some share in the transport of these boulders, but how much is uncertain.

In upper Baltistán where, as already stated, existing glaciers attain their maximum development, there are abundant evidences of a formerly much more extensive glaciation. Polished rock-surfaces, groovings, and 'perched blocks' occur abundantly in the Bráldu valley,—one of the tributaries of the Shigar river,—and from their position prove that the ice in places was once at least 1,500 feet in thickness. At the mouth of the Palma valley—a tributary of the Bráldu valley—the summit of a ridge of white triassic limestone, which is at least 2,000 feet above the level of the Bráldu river, is thickly strewn with gigantic blocks of porphyritic gneiss, which must have been brought from far up the valley. Some of the precipitous cliffs on the left bank, at a height of more than 1,000 feet above the river, are smoothed and polished. The upper portion of the valley still retains the U-shape so characteristic of glacial action; but in its lower part later denudational agencies have cut the valley into a V-shape, though

traces of the older condition are still retained in the form of ledges along the sides of the valley. These and other evidences afford unmistakeable proof that the present disconnected glaciers of the upper Bráldu river were once united, and reached as far down as Askole (Askoley). Below the latter place glacial markings are distinctly visible on projecting spurs of gneiss on the left bank of the river at the village of Hoto: similar markings are observable at Foljo, and it is very noteworthy that in both these instances the glacial markings have been protected from obliteration by a covering of alluvium; similarly situated spurs which lack this protecting coat having lost all traces of glacial markings. Other markings of old glaciers can be detected further down the valley, either on alluvially protected spurs, or on nearly vertical faces of rocks where the action of denudation is reduced to a minimum. The greater part of the Bráldu valley is distinctly V-shaped, but near its junction with the Básha valley somewhat suddenly expands, and assumes a U-shaped character. Here glacial markings may be observed close down to the present river level. Gigantic travelled blocks of gneiss strew the valley at this part, and 'perched blocks' may be observed in numbers on the neighbouring spurs. The lower part of the spur dividing the Bráldu and Básha valleys is smoothed and rounded by glacial action up to a height of some 1,200 feet, above which point its 'sky-line' becomes suddenly jagged and irregular. In the Shigar valley, for some distance below the junction of the Bráldu and Básha rivers, glacial markings have not been observed. The spur of dark schistose gness, separating the Shigar valley from the Indus valley, below the town of Shigar is, however, strewn with blocks of light-coloured granitoid gneiss and triassic limestone, which must undoubtedly have attained their present position by the aid of ice. At Skárdu, on the Indus, an isolated rock in the middle of the plain is covered with gigantic perched

blocks, some of the latter being distinctly polished and grooved; large blocks of transported gneiss also lie on the plain to the south of the fort, and some of these blocks appear to rest on certain lacustrine strata which will be described below. Near the fort some of these lacustrine beds are crumpled and contorted in a manner which it is difficult to explain in any other way than by the effects of the lateral pressure of a glacier, or an iceberg.

The foregoing observations indicate that either glaciers, which were probably the continuation of those now existing in upper Baltistán, or icebergs, formerly debouched on to the Skárdu plain, which has an elevation of something over 7,500 feet. It cannot, however, be affirmed that there is any proof that the whole of this valley was ever filled with ice. Large masses of moraine matter occur lower down the Indus at Katsúra, some sixteen miles below Skárdu; but these moraines were probably formed by a local glacier.

Well-marked traces of old glaciation are to be found on the high plateau of Deosai, between Baltistán and the Kishanganga valley, where, in spite of its lofty elevation (13,000 feet), glaciers do not exist at the present day. These traces mainly consist of distinctly ice-worn bosses of gneissic rock partially covered up by thick alluvial deposits.

In the district of Pángi, on the Chínáb, distinct traces of former glaciation have been observed by Col. C. A. Mc'Mahon,[1] who deseribes a precipitous rock-face at an elevation of about 7,500 feet above the sea on the left bank of the Chínáb, distinctly ice-grooved. The precipitous face of this rock has probably preserved its markings from obliteration. In the neighbourhood of Dalhousie, on the outer side of the Dhauladhár range, the same writer[2] has described what appear

1 "Records," vol. XIV., p. 310. 2 *Ibid*, vol. XV., p. 49.

to be undoubted glacial moraines at an elevation of about 4,700 feet. This observation is one of the most important in relation to the downward and outward extension of the old Himalayan glaciers. In general, wherever rock-bound mountain tarns exist it may be taken as fair evidence that ancient glaciers existed.

The facts given above prove that the glaciers of the Káshmír Himalaya were formerly of vastly greatly proportions than they are at present,—although the existing ones include the second largest in the world,—and that they existed at levels, and in districts where there are none at the present day. There is, however, no evidence to show that there was ever a continuous ice-cap over these mighty mountains; such evidence as exists pointing rather to the conclusion that merely the higher plateaus and some parts of the river valleys were covered or filled with ice. In many instances, as in the Indus valley at Skárdu, although there is distinct evidence of the former presence of ice in some form or another, yet it cannot be affirmed positively in what form this existed; or, if glaciers occupied the valley, whether the whole valley was choked with ice, or only isolated glaciers debouched into it here and there. Similarly the lowest limit to which glaciers reached must still be considered a moot point.

In spite of these evidences of former more extensive glaciation, there is no question but that taken as a whole the Káshmír Himalaya, in common with the rest of the same mountain system, does not bear the impress of an extensively glaciated country, in the manner in which this presents itself in Europe. The V-shaped narrow valleys, and the sharp rugged spurs and crags, together with the scarcity of ice-worn rocks, and the practical absence of lakes in the lower regions, being in striking contrast to the physical features of the Alps and the Welsh mountains. So marked indeed is the absence of

glacial features in many parts that it has even been attempted to disprove the existence of a former glacial period in the Himalaya.[1]

The very faint traces which the former glaciation has left on the face of the country even in the neighbourhood of the larger existing glaciers is a very noteworthy point. In connection with this point it will, of course, be apparent that as the ice of the glacial period began, through altering climatal conditions, to diminish, it would disappear first from the lowest and warmest regions to which it extended, while the regions in which it lingered the longest would be those in the immediate neighbourhood of the existing glaciers. Seeing then how indistinct are the traces of this former more extensive glaciation which remain in the latter regions, it is certain that in the lower regions, where the ice, if it ever existed, must have disappeared at a much earlier period, still less distinct traces of glaciation would remain. The forthcoming evidence presents itself in the foregoing order of distinctness, since while near the present glaciers *roches moutonnèes*, rock-groovings, moraines, and perched-blocks, are of not uncommon occurrence, in Káshmír proper moraines are not uncommon and rock-grooving is recorded in one instance, while in the Outer Hills blocks presumed to be glacially transported, and debris assumed to be of morainic origin are the only remaining traces. The absence of any decisive traces of glaciers in the Outer Hills is, therefore, only what is to be expected from the very faint traces which the old glaciers of the inner Himalaya have left behind them, and can in no wise be taken as evidence against the possibility of a former glaciation of the former regions.

Assuming that the glaciation of the Himalaya and Europe was approximately contemporaneous, which was almost certainly the case,

[1] J. F. Cambell. 'Quar. Jour. Geol. Soc.,' vol. XXXV., p. 98, *et seq.*

it remains to consider why the traces of this glaciation are so much less clear in the one region than in the other. Why, in fact, that in many parts of Europe, like North Wales and Scandinavia, whole mountains and valleys have retained the features impressed upon them by the ice of the glacial period, while in the Himalaya such features are only exceptionally preserved, and the general appearance of the country is not that of a glaciated one. One answer to this question is that in Wales and Scandinavia the whole face of the country was glaciated, and all the hills swept over by one continuous ice-cap, which, as already said, does not appear ever to have been the case in the Himalaya. Such a continuous ice-cap would undoubtedly leave far more lasting traces on the face of a country than would be left merely by the presence of large glaciers in the valleys. This solution will not, however, hold good when the Himalaya is compared with the Alps, as in both of these mountain systems there seems to have been no continuous ice-cap, but merely a vastly greater extension of glaciers in the valleys. The solution of this difficulty is probably that in the Himalaya the atmospheric erosive agencies have acted with a much greater degree of rapidity and energy than they have ever done in the Alps, and have thus obliterated to a far greater extent the evidences of a former more extensive glaciation. In the Outer Hills, and especially in the more easterly Himalaya, as at Dárjíling and the Khási hills, the annual rainfall is far greater than that of any part of Europe, and this, acting in conjunction with the wide extremes of annual temperature which prevail in so many parts of the Himalaya, must probably have exerted a far more powerful denuding effect than that which acts upon the Alps. Further, it is evident that, owing to the difference in latitude between the Alps and the Himalaya, at equal elevations, and physical conditions being the same, glaciation, wherever it existed, must have disappeared at an

earlier period in the latter than in the former region, and consequently that there has been in the Himalaya a longer lapse of time for denudational agencies to effect their work of obliteration. The combined effect of this longer lapse of time, and the more violent action of denudational agencies may not improbably have been sufficient to have produced the differences in the present physical features of the Himalaya and the Alps, although both alike have been once subjected to a glacial period of great intensity.

In conclusion, it may not be out of place to mention here a peculiar ice structure occurring in the sacred cave of Amrnáth (Ambernath), at the head of the Lidar valley in Káshmír proper. This cave, which is situated at an elevation of some 16,000 feet, is a large hemispherical hollow in the side of a cliff of white mesozoic dolomite. At the back of the cave there issue from the rock several frozen springs, the ice from which juts forth in spirals which subsequently reunite and form a solid dome-shaped mass of ice at the foot of the back wall of the cave: the size of this mass of ice, which is esteemed sacred by the Hindús, varies according to the season.

Evidences of igneous action.

In palæozoic, and again in eocene times, as will be fully shown in the sequel, there is abundant evidence that igneous, or volcanic, agencies were actively at work in the Káshmír Himalaya, as is proved by the outpouring of vast quantities of volcanic rocks. Remains of volcanoes themselves have not, however, been hitherto detected among any of the volcanic rocks; and none of the latter are known to have been erupted since the eocene period. The persistence of subterraneous thermal action is, however, indicated by the prevalence of numerous thermal springs, some of which are of relatively large size, and show evidence of having formerly been still larger. The

following list of these springs is mainly taken from the memoir by the late Dr. Thomas Oldham, edited by his son, Mr. R. D. Oldham,[1] supplemented by some observations made by the present writer. In the Outer Hills thermal springs occur at the following places, *viz.*:

SAIRA. On the left bank of a stream running into the Púnch river, near the village of Saira, above Kotli, in Púnch. Lat. 33° 37′. Long. 74° 02′.

RÁJÁORI (Rajawar). A hot spring, with a temperature of about 140°, is stated to exist at a place called Tandapáni, one march eastward of Rájáori. It is sulphurous, and a cold spring issues close by, from which the spot is named (*Tanda*, cold, and *páni*, water). Lat. 33° 18′. Long. 74° 25′.

AKHNÚR. Springs occur on the right bank of the Chínáb, on the Trikota hill, about 27 miles from Akhnúr. The water issues in jerks and falls into a basin, and is stated to be cold during nine months of the year, but hot in the winter. Lat. 32° 53′. Long. 74° 48′.

KIRAMCHI. To the east-north-east of Akhnúr, at Kiramchi, a tepid spring issues from the mesozoic limestone.

In the valley of Káshmír the following three occur, *viz.*:

THED. A spring, hot in winter, and cold in summer, situated at the village of Thed (Theed), on the Dál lake of Káshmír.

WIAN. At the village of Wian, in the district of Víhi, to the south-east of Sirínagar, and north of Pámpúr, there are three sulphurous springs with a high temperature, issuing from the limestone rocks; they are called *phúk-nág.*

1 "Memoirs," vol. XIX.

ISLÁMÁBÁD. Two sulphurous springs issue from the limestone rock at the back of the town.

In the Wardwan valley hot springs exist up the Farriabadi stream (Krish nalla of sportsmen), and in the district of Daghin, above Kishtwár.

On the Chínáb hot springs are stated to exist at Chatargarh, in Kishtwár; and there is another at Trioknáth, in Chamba territory.

In Baltistán thermal springs are abundant. The following are the chief, *viz.*:—

BISIL, on the Básha river; the spring here has a temperature of about 160° F.

CHITRUN, lower down on the same river. The hot spring here is the largest in the country, and has a temperature of about 110° F. The water is clear and tasteless. The name of the village is composed of the word *chu* or *tsu* (the same as *tso*), water, and *trün*, hot.

TOSHA, on the right bank of the Bráldu river.

HOTO, on the same. Three small ferruginous hot springs break forth near this place.

CHONGO, on the same. There is a large sulphurous spring at this place, flowing into a basin of travertine: the water has a temperature of 169° F.; and the spring was formerly larger than at present.

SKÁRDU. A spring is stated by Mr. Vigne to flow from the foot of the great rock of Skárdu. The name of this spring is Chitrun or Tsutrun, corrupted on some maps into Sneuron.

KHORKUN. A hot spring occurs above a village of this name on the Kondus branch of the Saltoro river,—a tributary of the Sháyok, in Baltistán. The temperature is given as 185° F.

In Ladákh the following are recorded, *viz.*:—

PANAMIK. About thirteen miles up the Nubra river two springs are situated at a village of this name: they are sulphurous and have a temperature of from 170° to 172° F. Travertine is deposited by these springs.

GOGRA and KYÁM. In the Chángchenmo valley near the halting places Gogra (Gokra) and Kyám (Kium) hot springs are numerous. One of these has a temperature of 150° F., and gives off carbonic dioxide with effervescence: it spouts up to the height of a foot or more from a dome-shaped deposit of travertine. The spring at Kyám has a temperature of 147° F.

CHIGAR. A spring, with a temperature of 70° F., is situated on the Tánktse road north of the trigonometrical station of this name (not marked on the accompanying map).

CHUSHÁL. At Chushál (Shushul), to the west of the Pangúr lake, there is a spring with a temperature of 96° F.

PÚGA. On the Púga river, a tributary of the upper Indus in the district of Rong, there are numerous hot springs, one of which has a temperature of 174° F.

TSO-MORIRI. In the neighbourhood of this lake there are numerous hot springs, some of which render the water of the southern end quite tepid.

A very remarkable manifestation of some form of igneous, or volcanic, action is briefly recorded by the late Dr. Hugh Falconer.[1] He states: "I have met with a most remarkable volcanic tract in Cashmeer, and, so far as my reading goes, without example elsewhere; a tract of alluvium with the strata elevated at a slight angle, and torrefied up to the surface to the condition of a well-burnt brick; but there is no outpouring of lava, and the tract is very circumscribed. Thirty-three years ago [this passage was written in 1837, which would make the date referred to 1804] the ground was so hot that the Hindoos of Cashmeer, simply by digging a few inches, were enabled to boil rice by the heat of the under strata. There must have been a layer of incandescent matter underneath; but strange, is it not, that it nowhere reached the surface?" From the mention of inclined alluvial strata in this passage, it is evident that the locality alluded to must be somewhere along the fringe of the Pír-Panjál range, although the present writer has not been able to identify the precise spot. There can be no question that, as stated by Dr. Falconer, the phenomenon was due to subterranean volcanic action.

The older Mohammedan historians mention that Káshmír was formerly very frequently visited by severe earthquakes, the effect of which is abundantly manifest in the shattered condition of many of the old Buddhist temples, like that of Mártand, near Islámábád. Earthquakes appear to be much rarer at the present day, the writer never having felt or heard of one during the eight years in which he knew the country. Severe earthquakes are recorded in the years 1552, 1669, 1780, and 1828; by the latter it is stated that about 1,200 houses were thrown down and 1,000 persons killed.[2]

1 "Palæontological Memoirs," vol. I., p, 567—note.

2 See Vigne, *op. cit.*, vol. I., p. 281.

The diminution in the volume of the thermal springs, and the present rarity of earthquakes, all point to the conclusion that subterraneous igneous action is now slowly dying out in these regions.

CHAPTER III.—GEOLOGICAL FORMATIONS.

Before proceeding to the description of the different rock-systems, it will render the scheme of the classification adopted in this memoir more readily understood if the following table of the chief geological divisions adopted be first studied. The grounds of this classification will be discussed under the head of each rock-system in the ensuing chapters. The first column of the table gives the major and minor divisions of the geological series in the area under consideration. The second column gives the larger European geological divisions which correspond to the Káshmír rock-groups; while in the two last columns the corresponding rock-groups of the more easterly Himalaya are given, taken from the works of Dr. Stoliczka and Mr. Medlicott :—

TABLE OF GEOLOGICAL FORMATIONS IN THE NORTH-WEST HIMALAYA.

Káshmír Territory.		European Equivalents	Spiti.	Simla District.
Alluvial system	Low-level alluvia, etc.	Prehistoric	The same	The same
	High-level alluvia, glacial, lacustrine, and karewa series	Pleistocene	The same	The same
Tertiary system	Siwalik series { outer inner	Pliocene	—	Siwalik series
	Sirmúr series { Murree group	Miocene	—	Dúgshai and Kasauli groups
	Sirmúr series { Subáthu group Indus tertiaries	Eocene	—	Subáthu group
Zánskár system	Chikkim series	Cretaceous	Chikkim series	—
	Supra-Kuling series	Jura and Trias	Gieumal group Spiti group Tágling group Para group Liláng group	Krol series
	Kuling series	Carboniferous	Kuling series	Infra-Krol series
Panjál system	(not generally subdivided)	Silurian Cambrian ?	Múth series Bhábeh series	Blaini series Infra-Blaini series
Metamorphic system	Metamorphosed Panjals, etc. Central gneiss	Palæozoic and Archæan	Central gneiss	Chor gneiss

CHAPTER IV.—THE ALLUVIAL SYSTEM, OR PREHISTORIC AND PLEISTOCENE ROCKS.

Deposits from thermal springs; alluvial and glacial deposits of the upper Indus basin; river plateaus and alluvial and glacial deposits of other valleys; lacustrine deposits of upper Indus basin; alluvial and lacustrine deposits of the Káshmír valley.

Deposits from hot springs.

The present thermal springs of upper Baltistán deposit considerable masses of white or yellow travertine, forming basins into which the jets flow. In the Chitrun and Chongo springs, the position of which has already been noticed, there are large masses of older deposit, at some distance from the present point of issue of these springs. At the Chongo spring, immediately to the eastward of the present vent, this older deposit of yellow travertine has, roughly speaking, a long diameter of 600 feet, a transverse diameter of 180 feet, and a thickness of 60 feet at its lower and thicker border. In form this deposit consists of a series of regularly formed semi-cylinders, placed one above another in a staircase-like manner, the summit of each semi-cylinder being fringed with a hanging curtain of stalactites. The whole deposit, though on an infinitely smaller scale, presents a great resemblance to some of the travertine deposits of the hot spring and geyser region of Yellowstone Park, in the United States. Some of the springs in upper Ladákh are stated to form similar deposits.

Alluvial and glacial deposits of the Upper Indus basin.

In the present memoir the alluvium of that part of the plains of the Punjab forming the southern limits of the area under consideration will not be described, as it belongs more properly to the geology of the peninsula of India. Accordingly, the first alluvial deposits to be noticed here are those of the almost rainless districts of the basin of the upper Indus and its numerous affluents, as far as they lie within the area under consideration. These districts, in common with other parts of High Asia, are from their climatal conditions peculiarly favourable to the preservation of soft alluvial and lacustrine strata, which in other countries would long since have been swept away. From this cause it happens that there exist in these districts enormous accumulations of these deposits, which from their very bulk, and the manner in which they respectively encroach, it is very often extremely difficult, or even impossible, to refer to their respective geological origins or age. It is in most cases absolutely impossible to distinguish definitely glacial from alluvial formations properly so-called, and the attempt has consequently been abandoned. It must not, however, be thought that this is entirely, though it doubtless is partly, due to imperfect knowledge of the formations themselves, since a moment's reflection will show that the observer has to deal with a very different condition of things than that to which he is accustomed in most parts of Europe. In North Wales, for instance, the geologist has to deal with one period when the whole country was ice-bound, and with a subsequent period when, as now, no glaciers of any kind exist. In the Himalaya the case is entirely different, for at the present time the district of upper Baltistán may almost be said to be in a glacial period, and in former times, as the old glaciers kept steadily retreating from the lower levels, the 'glacial period' would as successively disappear

from these lower levels, while it still existed at the higher ones. In place, therefore, of there having been one glacial period, there may be said in this sense to have been a host of such periods, and glacial strata in one region will be contemporaneous with the post-glacial strata of another. It will, therefore, be apparent that any chronological sequence founded on this basis can only hold good for one particular spot, and accordingly any attempt to divide the superficial strata of the whole area into stages in reference to the glacial period has been, perforce, abandoned.

The term alluvial, therefore, as employed here will frequently comprehend glacial deposits as well as those ordinarily classed under that term.

In the following account the writer is largely indebted to the observations of Mr. Drew,[1] from whose memoirs a great part of it has been compiled.

In the water-basin of the upper Indus and its affluents, Mr. Drew divides the alluvial formations into four sections, *viz.:* (1st) Loosened material; (2nd) Taluses; (3rd) Alluvial fans; and (4th) Alluvium proper; all being distinct from the true lacustrine deposits of the same regions. The first section does not require further notice. Taluses are defined as heaps of material fallen from higher ground, and lying at its foot, without any rearrangement by aqueous matter; this material lies at the natural limiting angle of slope, which is generally about 35°. Figure 1 of Mr. Drew's memoir in the "Quarterly Journal" shows such a talus in Nubra, on the Sháyok: the surface of this talus forms a curiously smooth regular slope. A second type, known as a 'fan-talus' is also exhibited in Nubra, and is represented in figure 1, reproduced from figure 2 of

1 "Jummoo and Kashmir Territories," and "Quar. Jour. Geol. Soc.," vol. XXIX., p. 441. *et seq.*

Mr. Drew's memoir. This form is caused by the material, instead

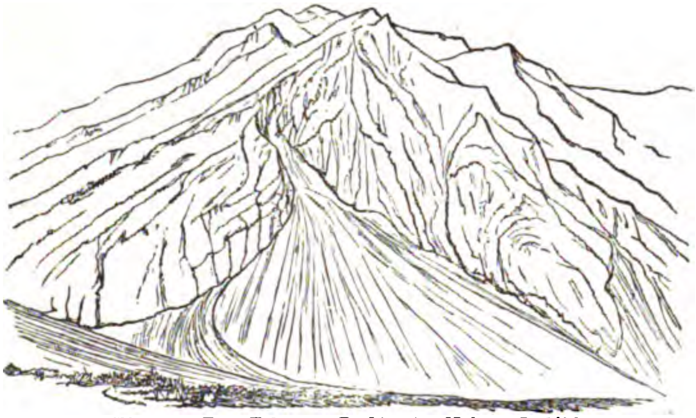


Fig. 1.—*Fan Talus at Deskit, in Nubra, Ladákh.*

of falling from a long line of cliff, being collected into a ravine, and allowed to expand at its mouth, when it finds its own level. Similar taluses are to be observed all over Ladákh; and near Leh itself some of these taluses almost cover the ridges from which they are derived.

The third form of structure, to which the name 'alluvial fan'

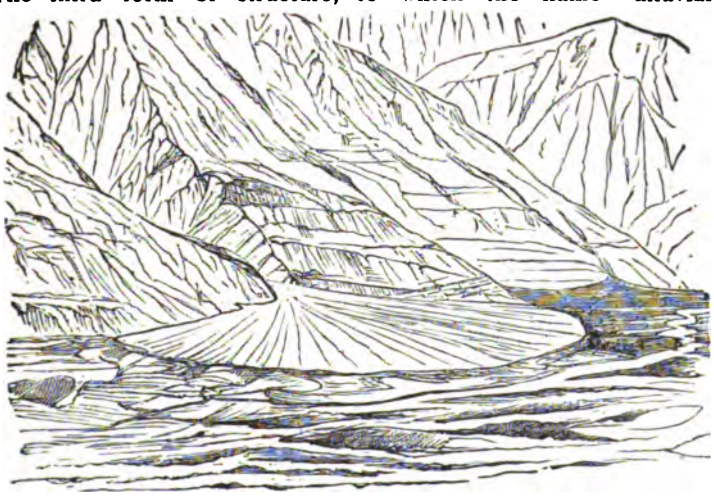


Fig. 2.—*Fan at Tigar, in Nubra, Ladákh; seen from the mountains behind Chardsa.*

has been applied, is also of common occurrence throughout Ladákh. These fans are found at the mouths of ravines opening into wider valleys. Figures 3 and 4 of Mr. Drew's memoir, the former of which is reproduced here (fig. 2) exhibit fine examples of this structure occurring at Tigar, in Nubra. The Nubra valley itself is a flat space filled by gravelly river alluvium, on to which the fans project; the radii of the larger fans being about one mile in length. These enormous fans are formed by the action of streams flowing down the side ravines, and depositing detritus in the form of successive hollow cones, one upon another; the section of the fan showing a stratified arrangement of the material in curved coatings. The slope of the surface of these taluses varies between 3° and 8°.

On the left bank of the Indus, opposite Leh, there is a great series of amalgamated fans. "There, from a series of ravines of a uniform character, project fans that have coalesced together, and now make a continuous spread of fan deposits nearly two miles in width, extending along the foot of the mountains for a distance of thirty miles." Similarly united fans are represented in figure 3, reproduced

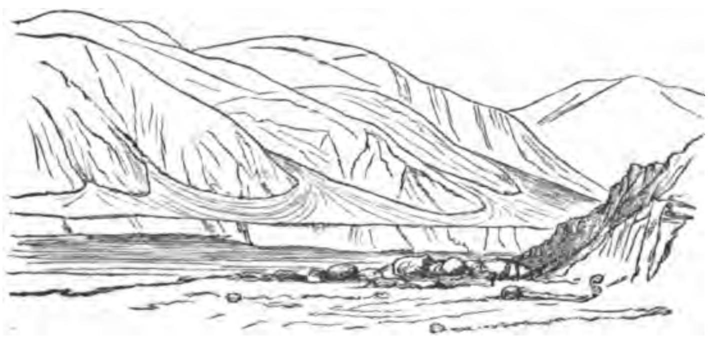


Fig. 3.—*Fans united* **(five miles south of Pamzálan, Chángchenmo valley, Ladákh).**

from figure 7 of Mr. Drew's memoir, near Pamzálan, in the Chángchenmo valley. It is generally upon these fans that the

comparatively small amount of cultivated ground in Ladákh is situated, but only a small portion even of these can be so utilized. These fans at their edges appear to be frequently interstratified with the river alluvium, thus indicating the contemporaneity of the two deposits.

At the north-western end of the line of amalgamated fans opposite Leh the Indus has cut off the terminations of the fans, making a steep cliff from fifty to one hundred feet in height, this cliff of course increasing in height the further the river cuts back into the fans. An example of this action is given in figure 4,

Fig. 4.—*Fan cut into by the River, with secondary fan formed in front* (four miles south of Pamzálan, Chángchenmo valley, Ladákh).

reproduced from figure 9 of Mr. Drew's memoir, from Pamzálan, which also shows the formation of a secondary fan by the ravine stream having cut down into the cliff of its original fan.

In other cases the original fan has been subsequently cut into by its own formative stream without the formation of a cliff by the

main river. Mr. Drew notices the instance of a large complete fan in the Chángchenmo valley, near the Chinese frontier, which at its periphery has been cut into to the depth of seventy feet by its own stream. Figure 5, reproduced from figure 10 of Mr. Drew's

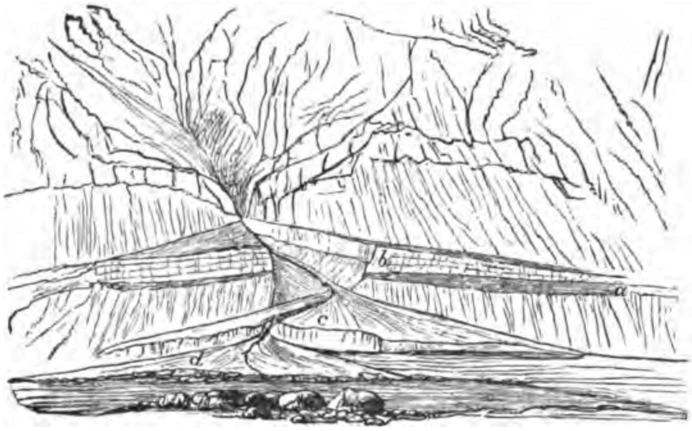


Fig. 5.—*Triple fan* (three miles above Tsotu, Chángchenmo valley, Ladákh).

memoir, illustrates an instance in which, while the main river has become a denudator and cut deeply into its own alluvium, the fan stream, though compelled by the lowering of the river alluvium to cut into its own deposit, has yet continued to form secondary and tertiary fans in its new cuttings. This illustration is taken from near Tsotu, in the Chángchenmo valley. In other instances by the lowering of the river alluvium the original fan has been cut into by its own stream, without any formation of a secondary fan.

Similar alluvial fans occur throughout Ladákh and Baltistán.

Coming now to Mr. Drew's fourth section,—alluvium proper,—his words may be quoted *in extenso*. "Although the accumulations last considered are in a general sense alluvial, yet for the purposes of my classification I must count as alluvium proper those deposits of a stream or river, which, while sloping in a direction coinciding with

the general course of the steam, are, as regards any line at right angles to that direction, level; that is, the surface of them is a plain inclined with the valley of the river, and not appreciably curving over to the sides of it; the word with this meaning agrees with one of the ordinary uses of it. . . . . . Alluvium, in this slightly restricted sense, is found in large quantities in the country of the upper Indus."

In Rupshu, near the sources of the Zánskár river, there is a flat alluvial plain about two miles wide, occupying an elevated level valley at a height of 15,000 feet above the sea. At one side of this plain there is a scarped ravine some 500 feet deep, with a river at the bottom, which has cut down to the rocky base of the alluvium. "The sides of the ravine are cliffs, in part worn into [rock-capped] pinnacles, in part sheer, and in part weathered into shingly slopes: the composition is beds of rounded pebbles, mostly of limestone, regularly stratified." Such an alluvium Mr. Drew attributes "to the action of the very stream that now flows at the bottom of the ravine cut through by the stream itself; it may, indeed, formerly have had a greater volume and force from the existence of a different state of climate." Here, therefore, as will be shown to be the case elsewhere, the streams were formerly accumulating, where they are now denuding, agents. Similar pebble alluvium occurs to depths varying from 200 to 400 feet along the route from Leh to Láhol, and in large quantities at Padam, the chief place of Zánskár, and in most of the wider river valleys. It does not appear that there is any constant height to which the alluvium reaches in the different valleys, nor is it probable that such was ever the case. In the Chángchenmo valley six distinct terraces of alluvium may be counted, and in other parts of the same valley the alluvium is highly inclined and curved, in such a

manner as to lead Mr. Drew to consider that this was probably effected by the thrust of a glacier.

There is considerable difficulty in accepting the latter view, since, as has been shown in the preceding chapter, glacial markings in the Bráldu valley are protected by high-level alluvium, which is probably approximately the same as that of Chángchenmo. There is the further difficulty in the view that the latter is all of preglacial age, since, if so, most of it ought to have been swept away at the time the valleys were filled with ice. The record of the relative time of the great extension of the Himalayan glaciers is, however, so obscure and unsatisfactory that in the present state of knowledge it is impossible to make any sound deductions from it, and many questions in connection with it must accordingly still remain *sub judice*: this question is again alluded to below.

Other examples of old high-level alluvium are mentioned by Mr. Drew, which in some places, as in the Taiyar valley—one of the tributaries of the Sháyok—attain a height of 350 feet above the present river level.

Coming next to the alluvium of the Indus proper Mr. Drew observes, "when the Indus enters Ladákh from Chinese Tibet, it is flowing towards the north-west through a flat alluvial plain at an elevation of about 13,700 feet above the sea. This flat, which lies between mountains of 19,000 and 20,000 feet high, has a width of about two miles, and continues like that for a length of some five-and-twenty miles. . . . . . . The alluvial substance is for the most part clay—sometimes a dark-coloured clay and sometimes drab clay—while at some parts not lately washed by the river it was sandy." All this alluvium is not above the present flood limits, and

is now in course of formation. This modern alluvium is the only one observable as far as the first village called Nimu. For some seventy miles below that place a great part of the course of the Indus lies in a rocky gorge which is almost impassable. Lower down, at the village of Upshi, the river cuts through the base of alluvial fans forming cliffs from 100 to 200 feet in height; the river alluvium being interstratified with them. From Tagna to Pitak, near Leh, there is another plain of modern low-level alluvium, which is largely cultivated. Descending the Indus valley as far as Khalsi, terraces of high-level alluvium are again met with, ranging from 100 up to 400 feet above the present river level. Occasional terraces of river alluvium occur along the Indus valley as far down as Rondu.

At Kargil, on the Suru tributary of the Indus, there is a wide open space between two rivers, covered with a thick deposit of high-level alluvial gravel, in which four distinct terraces have been observed, rising to a height of 600 feet above the present level of the streams. Near Páskim (Pashkam) somewhat similar deposits occur at a still higher level, but it is possible that some of these may be of lacustrine origin.

At Drás, higher up another branch of the Suru river, there is another similar alluvial expanse, occurring in terraces of two or three levels, the highest being about 120 feet above the stream: this alluvium, besides smaller stones, contains huge gneissic boulders, brought from the ridge on the north, and it seems not improbable that, as already said, ice may have had some share in their transport, though the view originally expressed by the present writer as to the entirely morainic origin of the terraces will probably not hold good.

On the plateau of Deosai, another feeder of the Suru river,

alluvial deposits of considerable importance occur: these mostly consist of gravels, with a gentle inclination, overlying and lapping round ice-worn bosses of rock, and, therefore, clearly either of post— or later glacial age. They contain blocks of gneiss, sometimes angular, and occasionally reaching to a diameter of thirty feet. Mr. Drew thinks it very probable that these deposits were formed mainly by the action of streams at a time when glaciers still existed on the plateau, and that they were continuous with the old high-level alluvia of the Drás and Indus valleys, while some of the larger blocks in them, situated further away from the mountains, may have been transported by floating river ice. This view appears to the present writer to be a very probable one, and will also apply to the case of the Drás alluvium. It should be borne in mind that supposing the alluvia of the higher elevations to have been accumulated (as the evidence of the subjacent ice-worn rocks of Deosai indicates), when the great glacial epoch was on the wane, they may yet perfectly well be contemporaneous with the high-level alluvia of the lower valleys, from which the glaciers had already completely disappeared. The suggestion that river ice was the transporting agent of the Deosai and Drás boulders may perhaps be applied to the case of the crumpling of the alluvium of the Chángchenmo valley, which would obviate the difficulties mentioned above; and would class this alluvium as 'post-glacial' in the valley itself, though 'glacial' in a more extended sense.

On the lower tributaries of the Indus in its course through Káshmír territory,—the Astor and Gilgit rivers,—there are similar evidences of old high-level alluvium. In the former valley near Dás (Dars) alluvial pebble beds are seen at a level of 400 feet above the present river; while at Astor itself there is a large plateau

coming out of the valley of the side stream, on which is built the fort. These alluvial deposits reach a height of from 600 to 700 feet above the present stream level, and from their containing blocks of huge dimensions are probably in part of fluviatile and in part of glacial origin, a glacier still existing at the head of the valley. Similar deposits extend up the Gilgit valley as far as Gákúj (Garkooch).

The foregoing high-level alluvial deposits considered as a whole indicate, in the words of Mr. Drew, "first a cutting of the ravines to something near their present depth; next a filling of them with material brought down by the streams to such depths as 200, 300, and even 600 or 700 feet, and this filling, though to varying depths, being general; lastly, a cutting down of the streams, through the alluvium they had formerly accumulated, to a depth sometimes less, but perhaps on the whole more, than they had originally reached." Mr. Drew concludes "that the greater deposits of alluvium were made at some part of the glacial period, and that the denudation of them occurred, or began, at the close of that period, when the lessening cold diminished the waste of the rocks." Different climatal conditions are considered to have been sufficient to have changed the rivers from accumulators to denudators without any change in the inclination of their beds. This 'change of habit' of the rivers, which is very general, not only in the Himalaya, but throughout northern Europe and Asia, makes it almost certain that some general cause has been concerned in the production of this change. Although it is unlikely that these deposits were formed at the height of the glacial period[1] when, at all events, many of the Himalayan valleys were

1 In a letter to the author Mr. Drew thinks it probable "that the greatest accumulation did not take place during the height of the glacial period; it must have been when the ground was exposed to frost rather than when covered by ice."

choked with ice, yet if the term 'glacial period' be used in the wide sense given to it above, *i.e.*, embracing a time when the glaciers were more extensive than now, though having disappeared from the lower valleys, and when the action of frost was far more intense, the above explanation accords well with the facts, as it indicates an abnormal period intercalated between two normal periods, and has thus the advantage over any theory involving changes of level, which, if they occurred at all, must have taken place at two distinct times (the one being the reverse of the other), *viz.*, at the close of the original 'prealluvial period' of denudation, and again at the close of the 'alluvial period' of deposition. Without, therefore, saying positively that the above is the correct explanation, it seems highly probable that some great climatal changes, during, or at the close of the 'glacial period,' have been connected with the accumulation of these vast quantities of deposit, which unquestionably indicate a very different condition of things from that prevailing at the present day, or in the 'prealluvial period." It may be added that, as will be shown immediately, since very similar deposits exist in the more outer Himalaya, if the above explanation be at all a true one, there will be a further argument for the former extension of glaciers to the latter regions.

It must, however, not be lost sight of that there are evidences of comparatively very recent changes of level in the neighbourhood of the Pír-Panjál, and it is, therefore, possible that in some districts this agency may have assisted in the formation of these deposits as a subsidiary aid to the great general cause.

It may also be well to mention here that in a recently published work[1] Professor J. D, Whitney has come to the conclusion that the

1 "The Climatic Changes of Later Geological Times, etc." Cambridge, U.S.A., 1882. See also a review in "Science" for March 9th, 1883, p. 141.

presence of large accumulations of pleistocene river gravels, and the diminution or desiccation of lake-systems in many parts of the world within historic and the later geological periods, indicates that at periods when these deposits were formed, and the lakes existed or attained their greatest development, there was a considerably greater rainfall than at the present day, and that there has been a steady secular diminution in this respect since the pliocene period.

In assigning a general climatal cause to the accumulations of the river gravels (and, as will be shown below, to the great development of lakes in the pleistocene period) the views expressed above are in accordance with those of Professor Whitney. The river gravels, however, as being accumulated during an apparently abnormal period of non-denudation, intercalated between two denuding periods, point rather to the conclusion that their inducing cause was a special one, although it may have occurred during an epoch of general secular desiccation. In this respect, as already said, the accumulation of the river gravels affords a strong presumption of their having some connection with the glacial period.

It must, moreover, not be omitted from mention that the writers of the "Manual of the Geology of India"[1] have suggested that these deposits were partly laid down when the level of the river valleys stood at the level of these deposits. Without denying that the rivers have considerably deepened their valleys in many places since the 'alluvial period,' it seems doubtful whether this explanation will hold. The deposits of alluvium are not mere 'shelves' on the sides of the valleys as is often the case in Europe, but they extend (as in the instances described by Mr. Drew) very nearly or quite

1 Pt. II., p. 672.

down to the present valley bottoms, and indicate that the valleys were formerly even larger than they are at present.

While stating that as a whole the Himalayan rivers are now denudators in place of accumulators, it has not been forgotten that, as in the case of the upper Indus, there are exceptions, though these are not sufficient to invalidate the conclusions arrived at above.

River plateaus, and alluvial and glacial deposits of other valleys.

In the valleys of the Middle Mountains and of many parts of the Outer Hills very similar plateaus of alluvial deposit are of almost universal occurrence, and in many instances attain to a great thickness. These deposits are in all probability approximately contemporaneous with the high-level alluvial deposits of the Indus basin, since they were formed in an accumulating period intervening between two periods of denudation. The 'fans' of the Indus basin are, however, wanting. It will be unnecessary to describe these deposits in any detail in all the different valleys, and, therefore, for certain reasons which will be apparent to the reader, those of the Jhelam, below the valley of Káshmír, are selected as a typical example.

The map accompanying the present memoir will show that in the high ranges, through which the Jhelam flows after leaving the valley of Káshmír, there occur masses of gneissic rocks on both sides of the valley, though they do not extend down to the base of the valley. These rocks, it may be mentioned, are indistinguishable in hand specimens from granite, and contain large porphyritic crystals of orthoclase. For some miles below the gorge of the Jhelam at Báramúla alluvial deposits are not very noticeable, but near the fort of Naushahra and onwards a thick alluvial deposit, chiefly composed of boulders derived from these granitoid rocks, is observable on either side of the river,

forming plateaus situated at least 100 feet above the river level. The boulders are all more or less rounded, and the interstitial matter shows generally but little signs of stratification. These boulders decrease in size further down the river, as the distance from their point of origin increases, except at places where fresh supplies have been carried down tributary valleys from the adjoining heights. Some of the boulders are upwards of 15 feet in length. As the boulders decrease in size the stratification of the deposit becomes more and more distinct: all the boulders have their long axes inclined up the stream and towards the river-bed at an angle of about 30°, so that one of their flattened surfaces is opposed to the flow of the present river, as is the case with the boulders in any modern river deposit. The surface of this alluvial formation forms a gently sloping plain, parallel with the inclination of the river, and forming disconnected plateaus here and there which have escaped denudation. At Uri, where several tributary streams join the Jhelam, there is a large triangular plateau of the alluvial deposit, consisting generally of the more or less worn tertiary rocks of the surrounding hills, mixed with occasional granitoid boulders. Below Uri the same formation continues, with a thickness of between 200 and 300 feet, and with the same gentle inclination, in which gneiss boulders are very scarce, except below Chakoti where they again become more frequent, and have probably been derived from a fresh source, though it is rather difficult to say where this source is as there is no gneiss in the Káj-nág range at this point: a few blocks of the gneiss can be traced as far down as the bend of the river at Muzafarábád. Excellent sections of this deposit are to be seen in the cutting of the new road near Chakoti, where it often contains water-worn boulders of the tertiary rocks reaching up to twelve feet in diameter. The formation can be traced to the limits of Káshmír

territory, and is clearly of fluviatile origin. Any explanation applying to the cause of the formation of the high-level alluvia of the Indus basin will apply equally well in this case; and, as already said, if the glacial period is connected with the formation of the former, similar conditions must have probably prevailed in the Jhelam valley at the time when its river was an accumulator in place of a denudator, as at present. The question of the glacial origin of the granitoid boulders has been already discussed in a previous chapter, when it was shown that they have very possibly been transported from their original position by ice action, but that they have been arranged in their present position mainly by the action of water. This view, however, does not prevent the possibility of their having been floated down the Jhelam by river ice, which may not improbably have been the case if glacial conditions did formerly prevail in the Jhelam valley, and local small glaciers, without choking the main valley, yet descended to its level.

Similar alluvial deposits are to be observed in the valley of the Chínáb, where the town of Kishtwár is built upon a large expanse of such alluvium at a height of several hundred feet above the level of the river. On the upper Kishanganga, in the districts of Gurez and Tilel, these alluvial deposits attain a very great development, forming extensive plateaus upon which most of the villages and cultivated grounds are situated. Many of these plateaus, as at Gurez itself, are several miles in length, and nearly half a mile in width. The deposits are stratified and contain more or less distinctly rounded boulders of the neighbouring and other rocks. In Tilel the plateaus are very continuous, but are cut through at intervals by the gorges of the tributary streams, rendering the road extremely tedious to the traveller.

Very similar high-level deposits exist in the extreme outer ridges of the Himalaya. Mr. Medlicott[1] describes them in the Jamu district as reaching to 400 or 500 feet above the actual river courses, and concludes "that the existing rock-gorges had been to a great extent cut out before their accumulation, then filled by them, and subsequently cleared out again."

It is probable that the whole of the high-level alluvial deposits described above should be referred to some part of the pleistocene period; and, as already shown, that the majority are connected with the close of the glacial epoch.

Lacustrine deposits of the Indus basin.

Throughout the basin of the upper Indus and its affluents, in its course through Káshmír territory, there occur other deposits mostly of lacustrine origin, and frequently attaining very considerable thickness. As in the case of the alluvial deposits of the same regions, these lacustrine strata owe their preservation in great part to the present absence of any quantity of rain in the districts in which they occur. They have been already described by several writers, foremost among whom are General Cunningham, Mr. Drew, Colonel Godwin Austen, and Dr. Thomson, whose writings have been already cited.

These strata (which cannot in general be shown on the small map accompanying this memoir) may be divided into two sections,—firstly those formed by extinct lakes, and secondly those formed by the existing lakes when they were larger than at present. Examples of the former are first found in the Indus valley in the neighbourhood of Gilgit; they occur again extensively at Rondu, but are most developed in the Skárdu district, where large masses of them occur on the right bank of the river adjoining the village of Kuardu,

1 "Records," vol. IX., p. 55.

and smaller outliers near the fort of Skárdu itself. They occur in many parts of the Sháyok valley, especially at Khápalu; and very similar strata are noticeable in some of the tributary valleys, as at Húshi, on the stream of that name flowing in above Khápalu; and at Lámayúru. They also occur at intervals along the Indus above its junction with the Sháyok, and are well developed at the village of Pitak, below Leh. General Cunningham[1] has published a map exhibiting the distribution of many of these strata. They usually consist of very fine buff-coloured clayey sand, or sometimes of nearly pure clay. They are always most distinctly stratified, and frequently contain dark layers of vegetable matter, and numerous shells of existing species of Mollusca. The general absence of any coarse material in them is particularly noticeable, and this, with their highly stratified character, and light colour generally distinguishes them from the proper alluvial deposits. From these deposits at Skárdu the following species of shells have been obtained by Col. Godwin Austen and Dr. Thomson,[2] *viz.*:—

Helix hispida.	Succinea putris.
—— oblonga.	—— oblonga.
—— pulchella.	Limnæa peregra.
Pupa eurina. Bens.	—— palustris (?)
—— huttoniana. Bens.	—— truncatula.
Zua lubrica.	Planorbis nanus. Bens.

Pisidium. sp.

It will be unnecessary to allude to all the places where these Indus valley deposits occur, and it will suffice to note a few points in connection with some of them. At Rondu they occur in patches of no great thickness, flanking the river valley. On the Skárdu plain

1 "Ladak," p. 136.

2 'Quar. Jour. Geol. Soc.,' vol. XX., p. 388. 'Pro. Zool. Soc.,' 1856, p. 185.

they are more than a thousand feet in thickness, forming bold scarped cliffs on the right bank of the Indus at Kuardu. The fragmentary remains of the same strata near the Skárdu fort are folded and crushed in a manner strongly suggestive of some form of ice-action. It has been inferred from the present distribution of these strata at Skárdu, that they formerly occupied the whole of the wide valley of the Indus at this place; and from their resemblance to the old subaqueous deposits of the Pángkong lake described by Mr. Drew,[1] and from their distinctness from the old littoral deposits of that lake described by the same writer, it seems pretty certain that they are really subaqueous, as distinguished from littoral deposits; whence it is probable that the old lake in which they were formed once occupied the whole of the valley. From their apparently underlying what appear to be glacially transported blocks, and from the contorted beds already alluded to, it would seem probable that the old Skárdu lake is certainly not younger than some part of the glacial period.

In Ladákh extinct lacustrine deposits are well shown at the village of Pitak, below Leh itself, fringing the gneissic rocks, and apparently underlying the alluvial fan of Leh; they consist of the usual distinctly stratified buff clays and fine sands, and form a very marked feature in the landscape.

Numerous instances of the total desiccation of lakes lying out of the main river valleys are described by Mr. Drew and General Cunningham, but it will suffice to notice the vast extinct lake which the former writer has shown once existed on the Lingzhíthang plain. It will, however, be unnecessary to go into the evidence on which this conclusion is founded, as it is given at length by Mr.

1 "Jummoo and Kashmir Territories," pp. 321-2.

Drew,[1] and accordingly only his conclusions need be cited. He observes that formerly "there was one lake stretching from near the Chángchenmo Watershed to the Kuenlun Mountains [north of Lingzhíthang] which made over what is now Lingzhíthang, a wide sea, 60 miles by 20, which reached through straights among the various ridges of which the Lokzhung Mountains are composed, and which spread northward over what are now the Kuenlun plains, penetrating far between the mountain spurs to the very base of the Kuenlun Mountains. At this stage there was *no watershed* between the Indian and Turkistán drainage; or if there were one it could only have been the higher of the two dams that confined the lake; it is possible that each dam alternately became the watershed, the waters of the lake sometimes going one way, sometimes another; and it is just possible that at some period the waters simultaneously flowed out both ways. The sinking of the surface of the water may have first begun by a lowering of one of the dams, but must at the last have been due to a change of climate, the present ratio of supply to evaporation of water not now availing, while formerly it must have availed, to spread the waters over the enclosed drainage-basins. At a stage in the sinking of the water the one lake must have become two. The waters themselves, by their currents and their shore-action, had accumulated deposits along the line of the Lokzhung Mountains, which, on their retreating became bars separating the two watery tracts, and have since become the watershed between the two enclosed drainage-areas." It is concluded that the dams of this extinct lake may have been very probably in part formed by moraines.

Turning to the second section, in Rupshu Mr. Drew[2] has come to the conclusion that the Salt Lake (lat. 33° 30′, long. 78°),

[1] *Loc. cit.*, p. 346, *et seq.*

[2] *Ibid*, p. 292, *et seq.*

which is now some five miles in length, formerly had an area of something between 60 and 70 square miles. The old deposits of this lake, consisting of sand, shingle, and laminated white clays, with remains of water-plants, *Lymnæa* and *Cyclas*, extend to 100 feet above the present level of the lake. They indicate that the lake, which now exists in a complete drainage basin of its own, without any outlet, formerly drained into the Zánskár river. They also show, however, that when the latter drainage existed it could not have lowered the lake below 60 or 70 feet above its present level, and it is accordingly concluded that its present level must be entirely due to change of climatal conditions. The dams of the lake have been caused by alluvial fans, probably aided by a moraine.

Along the shores of the Pángkong lake, as has already been incidentally mentioned, very similar deposits are to be met with, and also traces of old marginal beaches, indicating that the lake formerly stood at a much higher level than at present. The other large existing lakes afford very similar evidences. The waters of many of these lakes are now more or less saline, and without ontlet; but there is abundant evidence to prove that they were formerly sweet, and that streams flowed from them carrying off the surplus waters.

It is, therefore, certain that the existing lakes formerly received a much more abundant supply of water than they do at the present day, which atmospheric evaporation was not able to carry off, as it does their present supply, and it has accordingly been considered certain that the rainfall of the country must formerly have been much greater than at present. The evidence of the recent shells, already alluded to, which are found in the deposits of the extinct lakes, and in the old deposits of the existing ones, at heights where they cannot now

possibly exist,[1] has also led to the inference that the climate of these regions was formerly one of far less extremes than at the present day, and that animal life and vegetation were more abundant, and existed at elevations where they are now scarcely known. As the old lakes are generally situated on the lines of the present river valleys, and no traces of rock-basins are observable, there remains the question as to the manner in which these lakes were dammed, which is one of very considerable difficulty in some cases. In the instance of the Pángkong lake Mr. Drew[2] has shown that it is at present formed by the blocking of a rocky stream valley by an alluvial fan, which formerly stayed up the drainage water of the valley till it finally overtopped the dam and flowed over, until the time came when the climate changed, and there was no longer sufficient water to flow over, but the surface of the lake was kept at a constant level by the action of evaporation alone. The Rupshu Salt Lake, as already said, was probably dammed by alluvial fans and glacial moraines.

Taking the mode of formation of these lakes as typical ones, it is highly probable that many of the extinct lakes were formed in a similar manner; and this has been shown to be probably the case with the extinct Kuenlun lake.

The case of the enormous extinct lake of Skárdu, which must have had the Indus flowing through it, and have probably reached to a height of 1,000 feet above the present level of that river, is however, one of more difficulty. Mr. Drew considers it probable that it was formed by a glacial dam occurring lower down the Indus, and

1 See Cunningham, "Ladak," p. 190; and "Records," vols. VII., p. 15, and XIV., p. 183.

2 *Loc. cit.*, p. 324.

there is no doubt that if this explanation can be sustained it would afford an adequate cause. As has already been shown, however, there are some reasons to consider these deposits of preglacial age, though, on the other hand, it is somewhat difficult to see how so much of them could have escaped being swept away during the height of the glacial period if at that time the whole of the Skárdu valley was choked with ice. It may be that the Skárdu lacustrines were deposited in a lake dammed by a glacier, or glacial moraine, towards the close of the glacial period, when the Skárdu valley was more or less clear of glaciers, but some few still reached it, or may have sent off from higher levels large icebergs which crushed and contorted the strata of the lake bed. If a glacial dam did not cause the Skárdu lake, the only other possible cause would seem to be either a landslip or alluvial fans, but it is difficult to imagine these large enough to have blocked a valley as wide as the Indus for a period of time sufficiently long to have permitted the accumulation of these vast masses of deposit.

The above remarks will show how much remains for future observers before any satisfactory conclusion can be arrived at as to the relation of these extinct lakes to the glacial period. All that can be affirmed regarding them, is that some of them were not of later date than a portion of that period, that they afford indications that the rainfall was formerly greater than now, and that the climate during at least some part of their existence was such as to permit of the existence of molluscan life at elevations where it is at present impossible. To what extent the greater rainfall was connected with the former extension of the glaciers, or whether the indicated more genial climate prevailing at one time, took place during interludes in the cold of the glacial period, cannot be at present determined.

That the diminution and desiccation of the Tibetan lakes is a process still continuing is considered certain by Dr. Stoliczka,[1] who gives an instance of the disappearance of one lake since 1847, and who adds that "the time cannot be very far distant when all the lakes will cease to exist."

Alluvial and lacustrine deposits of the Káshmír valley.

In the upper basin of the Jhelam, forming the valley of Káshmír, very extensive alluvial and lacustrine deposits occur, which have been described by Mr. Drew, General Cunningham, Col. Godwin Austen, the present writer, and others, in the works and memoirs quoted in the introductory chapter. In his work on the "Jummoo and Kashmir Territories" Mr. Drew has devoted a whole chapter to the consideration of these deposits, with the title of "The Later Geological History of Kashmir," from which copious extracts have been made.

It may be observed in the first place that the Káshmír valley is distinctly basin-shaped, and that it has a length of about 84, and a width varying from 20 to 25 miles. The lowest point in the valley has an elevation of 5,200 feet, and the mean elevation is 6,000 feet above the sea. The lowest (Banihál) pass in the Pír-Panjál range, forming its outer boundary, is 3,000 feet above the level of the valley.

In its course through the valley the river Jhelam, below the town of Islámábád, flows through a plain of low-level recent alluvium, the distribution of which is approximately indicated on the map accompanying this memoir. The width of this plain varies from two to fifteen miles. It appears level to the eye, having in the first thirty miles a fall of 165 feet, but only 55 feet in the lower four-and-twenty miles. There is no doubt but that this alluvium has been

1 "Memoirs," vol. V., p. 130.

formed by the river in flood, and its formation may still be locally observed, though the operations of natural agencies have been greatly impeded by artificial embankments. It is chiefly composed of loam or clay, and it would be difficult to distinguish it from the deposits now forming in the lakes of the valley, though the latter may be more distinctly stratified. There is no evidence to show that any change of level has taken place since the deposition of this alluvium, which contains in many cases pottery and other works of art, of a comparatively modern date.

On the borders of this great plain of recent alluvium, or forming islands within it, there occur extensive elevated plateaus of alluvial or lacustrine material, which occupy a great portion of the valley, and to which the local name *Karewa* is applied—a name which has been generally adopted for these deposits. From their elevated position these karewas cannot generally be brought under irrigation, and are, therefore, in summer easily distinguished from the plain of the river alluvium, which in most parts is densely covered with rice-crops. In the central parts of the valley the karewas consist chiefly of loam, or loamy clay, with but faint indications of stratification, and with level surfaces. "They are divided from each other, sometimes cut into strips, so to say, by ravines of from 100 to 300 feet in depth; occasionally they are surrounded altogether by lower ground, but more generally they connect on to some of the mountains that bound the valley. Karewas and their dividing ravines occupy a width varying from eight to sixteen miles, along the south-western side of the valley, for a length of about fifty miles, from near Shapeyan to the river flat between Sopúr and Báramúla. Beyond Sopúr, again, the north-western end of the valley is mostly karewa ground. Lastly, on the north-east side of the valley, across the river, on its right

bank are spaces of karewas; in some cases these are in recesses made by retiring hills, in others they project out from spurs. The karewas adjoining the mountains have their surfaces inclined from the latter with a decreasing slope." On the south-western side of the valley the karewas reach upwards to an elevation of about 6,500 feet, or 1,300 feet above the lowest part of the plain of the river alluvium.

The flat-topped karewas always consist of horizontal beds, and in the neighbourhood of Islámábád attain a thickness of 300 feet. A characteristic section of a portion of a karewa near that town is given by Mr. Drew, and is as follows, *viz.*:—

	Feet.
Rather coarse drab or brown sand, with some small pebbles	20
Fine soft brown sand	3
Hard, very fine grained, sand	15
Blue sandy clay	5
Fine soft sand	5
Coarse sand like the uppermost bed	2

The coarse sand is occasionally hardened to stone; and in some places there occurs a fine impalpable buff sand, which Mr. Drew thinks may have been formed by the grinding action of glaciers on silicious rocks.

The sloping karewas are best studied along the flanks of the Pír-Panjál range, where they form a continuous series reaching from Shalúra in the north-west to below Shapeyan in the south-east. In the neighbourhood of Báramúla these beds are composed of yellowish clays, sands, gravels, and conglomerates, with an average dip of 10° to the north-east; the pebbles in the conglomerates seldom exceed three or four inches in diameter, and consist of the rocks of the old formations of the Pír-Panjál; the dip varies from 5° to 20°, and to the south-east stiff blue clays are frequently intercalated among

the yellow beds. Colonel Godwin Austen[1] estimates the thickness of these beds at upwards of 1,400 feet, and has obtained from them many species of land and fresh-water shells, all apparently of living forms, together with plant remains, and minute fish scales. Old land surfaces are indicated by anthracitic and lignitic layers, of from one to three inches in thickness. In a later memoir[2] the same author terms these tilted beds the Hirpúr series, from a village of that name near Shapeyan, on the Pír-Panjál road; this name will not, however, be adopted here. To the south-east of Báramúla, almost as far as Shapeyan, the lowest beds of these deposits consist of the above-mentioned stiff blue clays, but the conglomerates reappear at Hirpúr.

A section across the strike of these beds, towards the centre of the valley, such as may be seen along the road from the summer station of Gúlmarg to the capital, shows that as the distance from the Pír-Panjál increases, the dip of the beds gradually lessens, until it is scarcely perceptible: at the same time the blue clays and conglomerates disappear and give place to the brown loamy clays and sands of the flat-topped karewas of the centre of the valley. There does not seem to be the least sign of unconformity between any of the beds of the series, although false-bedding is frequent, and there would seem to be no doubt but that they all belong to one continuous formation, the lower beds of which are tilted and either conglomeritic or clayey, while the higher beds are undisturbed and clayey or sandy. The lower tilted beds may be called the "lower karewas," and the undisturbed the "upper karewas."

Reverting once again to the upper karewas in the neighbourhood

1 'Quar. Jour. Geol. Soc.,' vol. XX., p. 383.
2 'Brit. Assoc. Rep.,' *loc. cit.*

of Islámábád, Mr. Drew observes that "behind the town, below the level of most of the beds we have been looking at [the upper karewas], there are beds of a conglomerate of rounded pebbles of the [mesozoic] limestone, of all sizes, and upon these is an accumulation of large angular blocks. These beds lie sloping on the sloping face of rock; their angle with the horizon varies from 7° to 15°; there is sand and calcareous mud mixed up with the limestone pebbles." The relation of these beds to the upper karewas is not apparent.

At the mouth of the Sind valley, on the north-eastern side of Káshmír, there are thick deposits of conglomerate, sand, and gravel, with a slight inclination towards the centre of the valley of Káshmír, but whose relations to the upper karewas are likewise not apparent.

From the similarity of the conglomerates of Islámábád and the Sind valley to those of the Pír-Panjál it would seem highly probable that these also belong to the lower karewa group.

Before considering the manner in which these deposits were formed two points in connection with them must be noticed. In the first place, it appears that the great development of the conglomerates exists on the present lines of drainage; thus they are in great force at Hirpúr, on the stream flowing from the Pír-Panjál pass; again at Báramúla, on the Jhelam, where it flows out of the valley; at the mouth of the Sind river; and at Islámábád, on the Lidar. Minor developments occur on the smaller Panjál streams, as below Gúlmarg, It would, therefore, seem pretty certain that the conglomerates are, at all events in part, stream deposits.

The second point is the lówer boundary of the valley of Káshmír. At the present time the Jhelam makes its exit from the

valley through a narrow rocky gorge a short distance below the fort of Báramúla. This, however, does not appear to have been the original exit from the valley, since to the left (south-east) of the present gorge there is first a hill of slate, and then a long high ridge of tilted lower karewa deposits, over which the road passes, which blocks another gap, and forms the present boundary of the valley. The bottom of these deposits is not seen, but it is probable that if they were removed the rocky bottom would be lower than the present gorge of the Jhelam. The open plain which occurs below this ridge of lower karewas would, in the absence of the latter, form a part of Káshmír proper. There are traces of the same deposit for some miles below the Báramúla ridge. It will be at once apparent from the foregoing remarks that until the depth of the lower karewas of the Báramúla ridge is known, it is impossible to say whether the valley of Káshmír is a true rock-basin, or a blocked river valley, but in the opinion of the author it is most probably the latter.[1]

The question as to the manner in which the karewa deposits were formed may now be taken into consideration. From the great similarity in the petrological characters of the lower karewas (which have only been detected along the sides of the valley, fringing the mountain ranges, and probably do not extend across the valley) to the higher Siwaliks of the Outer Hills (described in the following chapter), it is highly probable that the two series have been deposited in an analogous matter. In the case of the Siwaliks it has been proved that these beds are not of lacustrine origin, but have been laid down by the action of rivers, torrents, and rains, and they may conveniently be designated as "wash deposits." In the karewas, as already said, the presence of thick beds of conglomerate near the

1 The authors of the "Manual" (pt. II., p. 673) hold a contrary opinion.

present valley of the Jhelam at Báramúla has led to the inference that these beds were probably deposited by the river itself, which must then have flowed out from the valley in a course not very far removed from its present one; if this be correct no lake could have existed here at that time.

With regard to the upper karewas, it seems difficult to imagine how a series of fine clayey and sandy deposits, perfectly horizontal, and extending completely across a wide and open river valley, and attaining a height of more than 200 feet above the level of that valley, could have been accumulated without the aid of a dam lower down the valley by which its waters have been ponded back. Accordingly, the only explanation of the mode of formation of the upper karewas that presents itself is that Káshmír was formerly occupied by a vast lake, of which the existing lakes are remnants. Mr. Drew estimates that at one period of its existence this old lake must have reached a level of nearly 2,000 feet above the present level of the valley. This estimate is, however, probably far too high, as it is made to include the sloping karewas of the Pír-Panjál, which are probably not of lacustrine origin at all; and, even if they are, they were probably horizontal when deposited, and far below their present level.

The question as to the nature of the barrier which dammed this old lake cannot be certainly determined, until it is finally decided whether the lower karewas of Báramúla are true lacustrine, or 'wash' deposits. If they are the former, the old lake must have continued below the Báramúla ridge; but if, as seems probably the case, they are the latter, this ridge may have formed the boundary of the lake. On the latter hypothesis it may be that the tilting of the lower karewas of Báramúla, which was probably connected with a general

rise of the country along the whole length of the Panjál range, may have caused the valley of Káshmír, which was previously an open river valley, to have become elevated and blocked at its lower end in the neighbourhood of Báramúla, and that in the basin thus formed the upper karewas may have been deposited, with their southern edges resting apparently conformably on the tilted beds of the lower karewas. This basin may have been subsequently drained by the river cutting down the present rock-gorge at Báramúla. Should this explanation be the true one, traces of the 'overlap' of the upper karewas on the lower beds of the same series ought to be detected.

Should it be that the lower karewas are in part of lacustrine origin, then it will be necessary to assume that the barrier existed below Báramúla, and the most likely place for its occurrence would be the narrow gorge of Rámpúr, some distance below Naushahra. As, however, it is highly probable that the former solution may be the correct one, it would be idle to discuss what might have been the nature of a barrier at Rámpúr, which may never have existed.

The whole question, however, requires further light thrown upon it by an observer well versed in the study of similar deposits, before there can be any hope of arriving at any very satisfactory conclusions, as to the barrier which dammed the old Káshmír lake, and the relative period of its existence.

With regard to the age of the karewas, their considerable geological age is indicated by the tilting which their lower beds have undergone, and by the amount of denudation which they have suffered, as well as by their relations to the low-level alluvium of the Jhelam. The lower karewas, bear, as already said, a very marked and striking resemblance to the topmost Siwaliks of the Outer Hills, which are likewise tilted, and have a

similar north-westerly strike. In the Outer Hills, the period of disturbance did not extend down to the post-Siwalik deposits (? higher pleistocene), and it seems, therefore, highly probable that the same disturbance may have acted on the upper Siwaliks of the Outer Hills and the lower karewas of Káshmír. If this be so, the age of the later must be either lower pleistocene, or the very highest pliocene, whichever the topmost Siwaliks may be; while the upper karewas may belong to some part of the pleistocene period. It would seem likely, as already said, that the elevation of the Pír-Panjál, which probably caused the tilting of the karewas, took place during the later part of the lower karewa period, and that the upper karewas were deposited in apparent conformity on the inner border of the tilted lower beds.

The glacial period presents the usual difficulties and perplexities in connection with these lacustrine and wash deposits. If, as seems probable, they are in great part of pre-glacial age (although, from the presence of what has been supposed to be glacial mud, their upper beds, as Mr. Drew suggests, may be of glacial age), it is difficult to see how they were preserved, if the Káshmír valley were ever filled with ice. This difficulty may perhaps be solved if it be considered that although glaciers descended to the level of the Káshmír valley, yet they never filled it with ice; and this may really be the clue to the problem, both here and in the case of the Skárdu lacustrines, which have already been discussed. This view, of course, involves the conclusion that the glacial period in these regions was not so intense as has sometimes been supposed.

CHAPTER V.—THE TERTIARY SYSTEM.

SECTION A, — THE SUB-HIMALAYAN TERTIARIES.

General remarks: classification: the Siwalik series: the Sirmúr series: general relations of the system: further conclusions to be derived from the system.

General Remarks.

Having now described the supra-tertiary rocks, the next system presenting itself for consideration is that of the tertiaries themselves, and of these the first to be considered are the tertiaries of the Outer Hills,[1] or the Sub-Himalayan system of Mr. Medlicott. Some difficulty has been found in regard to the treatment of these rocks here, since they have already been so fully described in other publications, that it might seem waste of words to repeat these descriptions here. As however it is necessary to describe some of them, in order to illustrate the tertiaries of the inner Himalaya in the upper Indus valley, it has seemed best to include the whole of them in this description, especially as without it this memoir would be incomplete. This description will, however, be brief, and a very large amount of detail, for which the reader may refer to the "Manual" and other publications of the Geological Survey, will be omitted; and it will not be necessary to give lists of the numerous vertebrate forms, whose remains have been obtained in such quantities from some members of the upper tertiaries, as these have but little bearing on geology

1 The possibility of some of the higher beds being of post-tertiary age need not interfere with the general application of the term "tertiary."

proper, and are fully described in other publications of the Survey.[1] Some of the more striking physical features of the Outer, or Sub-Himalayan Hills, have been already indicated in the introductory chapter, and the chief characters of the different rock-groups may, accordingly be at once considered.

Classification.

In the "Manual of the Geology of India,"[2] the following classification of the sub-Himalayan system is proposed—*viz.*,

1. Siwalik series	Upper	
	Middle	
	Lower (Náhan)	
2. Sirmúr series	Upper (Kasauli)	
	Middle (Dugshai)	
	Lower (Subáthu or nummulitic).	

This classification is chiefly founded on the relations of the rocks in the more easterly Himalaya (Simla district), where the minor groups are well defined. In the country discussed in this memoir the two high groups of the Sirmúr series cannot be clearly distinguished, and they are replaced by what is known as the Murree group, which may, however, also contain some representatives of the lower Subáthu group, and also some of the higher Nahán group,—the two series following in conformable sequence. Similarly the middle and lower Siwaliks of the Jamu Hills cannot be satisfactorily distinguished from one another, and, therefore, the Siwalik series will here be divided only into an inner and an outer group, these terms being less liable to create confusion than an extension of the term lower Siwalik. The following table will explain this arrangement:—

1 See "Palæontologia Indica."—Series X.
2 pt. II., p. 522.

		Jamu District.	Simla District.
Siwalik series		Outer................	Upper
		Inner................	Middle
			Lower (Náhan)
Sirmúr series		Murree group	Upper (Kasauli)
			Middle (Dugshai)
		Subáthu group	Lower (Subáthu)

It will be apparent from this table that the distinction between the two series is really only an arbitrary one adopted for the sake of convenience, and for correlating these rocks with the Simla tertiaries.

The Siwalik Series.

The Siwalik series, as above defined, comprehends the two zones of strata forming the outermost ranges of the Sub-Himalaya. The outermost of these two zones preserves an approximately equal width throughout its extent. It crosses the valley of the Rávi without any inward bending of its inner boundary, in which respect it is in marked contrast to the inner zone; but at the valley of the Chínáb, it makes a very marked inward bay, or bend; while it has a second bay, coincident with the general change in strike of all the rocks, at the Jhelam. Petrologically, this group consists either of coarse conglomerates, or of fine, brown clays; the latter being indistinguishable, in hand specimens, from the modern alluvium of the Punjab. The conglomerates occur mainly on the lines of the larger rivers, being replaced in the intervals by the clays. They are frequently made up of the coarsest shingle, like that now found in the bed of the Chínáb, and the other large rivers, and are derived from the older rocks of the Middle Mountains. The strike of the outer Siwaliks is most regular, and the beds, although elevated at all angles up to and overtopping the vertical, are never contorted.

Minor developments of conglomerate occur occasionally far away from the present river valleys, but the pebbles in these beds are composed of fragments of the local rocks, and are not derived from the inner ranges. It may, accordingly, be considered as certain that the present river valleys existed at the time the upper Siwaliks were deposited.

From the topmost of the outer Siwaliks numerous remains of vertebrates of a very modern type, in one instance identical with a species (*Bubalus palæindicus*) from the pleistocene of the Narbada valley, have been obtained, from which it has been suggested that these beds may belong to the pleistocene period. There is, however, the difficulty of referring both these highly disturbed strata, and the horizontal high-level alluvial deposits of the same districts, already noticed, to the same epoch, as they must evidently be widely separated in time. Still it is not impossible that the pleistocene period may have been of sufficient duration to have embraced both these widely separated formations. If this should eventually prove correct, it is manifest that there will be no break between tertiary and lower post-tertiary.

The inner Siwaliks, in regard to their strike and the amount of disturbance which they have undergone, agree with the outer group At the Rávi their outer border preserves a regular direction, but their inner runs some way up the valley in a loop. At the Chínáb valley the zone of these rocks, which is elsewhere more than twice the width of the outer Siwaliks, becomes suddenly constricted to about a third of its normal width. In the neighbourhood of the Jhelam valley, where there is another similar in-running loop of these rocks, there are several inliers of the inner Siwaliks exposed on anticlinal lines in the midst of the outer group, while there are outliers of the latter on synclinal lines within the zone of the inner group. The zone of inner Siwaliks is traversed by two great anticlinal lines

of flexure, which follow the main direction of the zone, except in the trans-Jhelam district, beyond the limits of the country under consideration.[1] The innermost of these great anticlinals, which is partly faulted, crosses the Rávi valley at Basoli, and here exposes in its centre an inlier of the lower Murree beds; it then sweeps up to the extreme inner boundary of the zone, on the Chínáb at Riási (Riassi), where it is in contact with an inlier of mesozoic limestone; it again sweeps down to near the middle of the zone, exhibiting a small inlier of the Murree group at Naushahra[2] (unfortunately omitted on the accompanying map), and a third on the Púnch river, below Kotli. Where it makes its great bend on the Jhelam, this anticlinal is also a broken one, its inner border in the trans-Jhelam country being formed by the rocks of the Murree group. The outer anticlinal has the same general direction, and exposes the Murree beds on the Púnch river. At the valley of the Chínáb the inner, or Basoli-Naushahra, anticlinal curves northwards into actual or apparent continuity with the eastern face of the Riási bay, thus cutting off the inner Siwaliks of Udampúr.[3] While both anticlinals make a large inward deflection at the Chínáb, on the Rávi only the inner one makes a slight bend, the outer sweeping straight across the valley.

Petrologically the inner Siwaliks consist of a clear pepper-and-salt grey sandstone, sharp and fine in grain, generally soft, and occurring in massive beds. There are very rarely discontinuous, thin bands, and nodules of earthy limestone; and the sandstone itself sometimes becomes highly calcareous, forming hard nodular masses. This is especially the case in the neighbourhood of organic remains,

1 For the course of these anticlinals and other flexures see the map facing p. 155 of the IXth volume of the "Records."

2 This must not be confounded with the village of the same name on the Jhelam.

3 See "Manual," pt. II., p. 567.

where the rock is often of intense hardness. The sandstone of the lower beds, approaching the Murree group, is harder than that of the upper members of the series. The softer sandstones are exactly like a consolidated form of the sand now found in the beds of the larger existing rivers. Bands of red clay, of varying thickness, occur here and there in the series, and often become more frequent nearer the underlying Murree group. It is probable that in the great valleys of the Rávi and Chínáb certain conglomerates occurring north of Basoli, and at Riási, belong to the upper part of the inner Siwaliks.[1] The thickness of the whole Siwalik series probably reaches as much as 10,000 feet in certain places, but there is considerable variation in this respect, and no exact measurements have been made.

The inner boundary of the Siwalik series in the Jamu Hills appears to be mainly a faulted (anticlinal) one, as is indicated by the comparative straightness of this line on the map; and by the fact that in the field it is found that beds of different horizons are in contact on either side of the line. Towards the valley of the Jhelam, however, this fault gradually dies out in an expanded anticlinal flexure, and there is then a complete transition from the Siwalik to the underlying Sirmúr series.

It is from part of the inner Siwalik zone that the great majority of the vertebrate fossils, which form such a characteristic feature of these rocks, have been obtained, and which, as already said, are in course of description in other publications of the Survey.[2] The conclusion arrived at from the study of these remains, and certain molluscan fossils, mainly of existing Indian species, is that the main fossiliferous Siwalik zone, does not date further back than some

1 See "Manual," pt. II., p. 568.
2 See "Palæontologia Indica," Series X.

portion of early pliocene time, and the series may accordingly be referred to that period, with a possibility of the higher group reaching up into the pleistocene. It may be added that the Siwaliks of the Jamu Hills are not so productive of these fossil remains as those of the trans-Jhelam districts.

The Sirmúr series.

Coming now to the underlying Sirmúr series, their distribution and characters must be treated rather more fully, as their north-westerly termination has hitherto only been described in a preliminary paper.

A glance at the accompanying map will show that the upper group of this series is the one chiefly developed in this area, and that it forms a zone within the Siwaliks, marked here and there by outcrops of the underlying Subáthu, or nummulitic, group. At its south-eastern extremity, in the valley of the Rávi, the zone of the Sirmúr series is extremely narrow, being somewhat less than half-a-mile in width. This zone makes here two very sudden bends, almost at right angles, the river between the two bends running along, instead of across, the strike of the rocks. These bends, which coincide with similar ones in the older rocks of the Middle Mountains, are probably due to the sudden diminution in the width of the crystalline axis of the Dhauladhár range at the valley of the Rávi. To the westward of the Rávi the Sirmúr zone expands, very suddenly at first, and subsequently more gradually, until in the Púnch district it attains a width of more than twenty-five miles. To the north-west of Uri, where the Jhelam leaves the Middle Mountains, the Sirmúr zone again begins to diminish in width, till at Muzafarábád it is only some ten miles across: above that place it once more expands and forms a large terminal bay, extending some twenty miles northwards into the valley

of the Kúnhár river. The whole of the north-easterly boundary of this great lower tertiary zone is formed by the rocks of the Murree group (with the possible exception of some beds near Uri), which are in contact with the pre-tertiary rocks of the Pír-Panjál range. On the western side of the Muzafarábád bay, however, the underlying Subáthu, or nummulitic group, is in contact with the outer border of the older rocks. To the south-west of Muzafarábád the Murree group extends into the trans-Jhelam districts which are foreign to the subject of the present memoir.

Petrologically the rocks of the Murree group consist of grey and purple sandstones, often of intense hardness, alternating with purple or red clayey shales, with occasional concretionary bands, and rare beds of thin blue limestone. A very characteristic rock is a variety of this hard purple sandstone, in which there are numerous kernels of a hardened buff clay. Thin beds of fine conglomerate are of not very rare occurrence; and in the neighbourhood of Chaneni, on the Choti Tavi river, Mr. Medlicott notices[1] extensive coarse conglomerates occurring near the inner boundary of the Murree group. The sandstones of the Murree group are but a more hardened and darker form of the Siwalik sandstones, and in places, as in the Jhelam valley below Muzafarábád, where the rocks of the Siwalik and Sirmúr series are in continuous sequence, there is such a complete transition from the soft grey pepper-and-salt Siwalik sandstone to the hard purple Sirmúr sandstone, that only an arbitrary boundary can be drawn between the two series. Occasionally thin layers of carbonaceous matter occur in these rocks, as on the Jhelam at Kohála, immediately above the bridge leading into Káshmír territory.

1 "Records," vol. IX., p. 53. It should be observed that there are two rivers bearing the name of Tavi (or Tawi) in the Jamu Hills: one of these the Bari (big) Tavi flows through Naushahra, and the other the Choti (little) Tavi, through Chaneni, and close to Jamu (Jummoo).

It has not been found practicable to form any near approximation to the thickness of the Murree group, but it must reach to many thousands of feet. In many places, as in the Jhelam valley, the dip and strike of these rocks are very steady over large areas, and although the rocks themselves are extensively folded, and often inverted, they seem in general to be less contorted than many of the pre-tertiary rocks.

In the Káshmír area these rocks appear to be in general totally unfossiliferous, but in the year 1881 the present writer was fortunate enough to discover in the red clays near the village of Chakoti, on the Jhelam, a portion of a palm frond, which Dr. Feistmantel[1] has referred to *Sabal major*,—a species of palm characteristic of the lower and middle miocene of the Continent of Europe. Remains, probably belonging to the same species, have also been obtained from the Kasauli group in the Simla district.

Although the remains of plants are of much less value in fixing geological horizons than are those of animals, yet in this case the evidence afforded by these palm-leaves, as supplementary to stratigraphical evidence, is of considerable importance. Thus the latter evidence shows that the Murree group is intercalated between the pliocene Siwaliks and the eocene nummulitics, which, the whole series being continuous, would afford *primâ facie* evidence that the former is of miocene age. This conclusion being supplemented by the occurrence of a characteristic miocene plant in the Murree group may probably be considered as correct. It must not, however, be considered as at all likely that the upper and lower boundaries of the Murree group coincide precisely with the limits of the miocene of Europe, as it is quite probable that their higher beds may reach

1 "Records," vol. XV., p. 51, and plate.

into the pliocene, and their lower into the eocene. It would, of course, be preposterous to assume for one moment that geological divisions in the Himalaya, founded on the petrological characters of the rock-groups, should exactly coincide with time-periods founded on the rock-series of Europe.

The next subject for consideration is the Subáthu group, and the relation of the whole Sirmúr series to the older rocks. It has already been stated that the outer boundary of the Sirmúr zone (exclusive of inliers in the Siwaliks) is on the line of a faulted anticlinal, dying out near the Jhelam. On this line a few miles to the west of the Rávi, on the Píni (Pine) river, there occurs a small outcrop of earthy limestone containing nummulites, in the midst of a great section of bright red clays and pale greenish sandy beds.[1] In the absence of these nummulites these beds would have been certainly referred to the Murree group, and their occurrence demonstrates how extremely intimate is the connection between this group and the underlying Subáthu rocks.

Still further to the north-west, in the neighbourhood of the Chínáb valley, a very remarkable feature occurs on the same line. The inner Siwalik boundary, in place of being in contact with the Sirmúr series, adjoins a huge inlier of older limestone, which will be described in a subsequent chapter, while the outer Sirmúr boundary sweeps round to the north of this inlier. The beds immediately resting upon the older rocks are highly nummuliferous, and after sweeping round the two sharp ends of the inlier, are continued in an irregular line from its north-west point to the Bari Tavi valley, in such a manner as to show that this limestone exists on an anticlinal axis, faulted on its southern side, which has been thrust up so as to

1 See "Records," vol. IX., p. 52.

bring the lower beds of the Sirmúr series into view. It has been already shown that in the bay at Riási on the southern face of this inlier, the union of the Basoli-Naushahra anticlinal with the southern faulted border of the old limestone, has cut off the lower Siwalik beds, bringing higher beds into contact with the limestone. Smaller isolated patches of the Subáthu rocks are found here and there on the top of the inlier of limestone, leading to the inference that it was once completely enveloped with these deposits. Further again to the north-west, in and near the Púnch valley, two similar inliers of the old limestone, similarly fringed with nummulitic rocks, occur on and to the north of the same Siwalik-Sirmúr boundary line, which are likewise broken and faulted on their southern faces.

The Subáthu group in these regions consists at the basement of a peculiar pisolitic clay, identical with the basement bed in the typical Subáthus of the Simla district, and also in the same group of the Salt-range of the Punjab. This clayey band is normally highly ferruginous, but by removal of the iron it not unfrequently becomes nearly white. It has been suggested[1] that this bed may have some connection with the high-level laterite of peninsular India, which is not improbably on the same geological horizon. Immediately above this band there occurs a layer of carbonaceous matter, with occasional thin strings and small pockets of pure coal, which, together with the similar deposits already noticed as occurring in the overlying Murree beds, have been the fruitful source of much misspent energy and baseless expectations. A band of pure blue or buff limestone, of great constancy, reaching to several feet in thickness, and frequently crowded with nummulites, succeeds the coaly layer, and itself gradually passes upwards into splintery olive and purple shales, from which there is again a

1 "Manual," pt. II, p. 563.

transition into the typical rocks of the overlying Murree group. Immediately underlying the characteristic bottom Subáthu beds there is very commonly found a sort of silicious breccia; the perfect angularity of all the fragments of which suggest that it was formed from rocks in the immediate neighbourhood. Iron-ore, occurring in the form of strings and nests of cellular limonite, is of very common occurrence in this breccia, and has formerly been extensively worked at the north-westerly termination of the Riási inlier of limestone. In every place where they are exposed, the rocks of the Subáthu group always lie in strict apparent conformity to the older limestone, a feature which is common to the tertiary and older rocks of other places, and whose import will be alluded to below. In the second inlier of limestone higher up the Chínáb, to the north of the Riási inlier, none of the Subáthu beds are exhibited, the Murree beds being in direct contact with the old limestone on all sides; and having a north-easterly dip on both north and south sides. It is probable that on the southern face of this inlier the junction may be a faulted one, but on the northern side the Murree beds seem to directly overlie the limestone, with every appearance of strict conformity, probably indicating that the older Subáthu beds were never deposited in this place. It is evident that the Riási line of nummulitic and older rocks is a continuation of the anticlinal axis of the Dhauladhár ridge, which, as is so often the case with such features in the Himalaya, is thrown into large open waves at right angles to its strike.

Another great anticlinal axis runs from some distance north-west of Rájáori through the town of Púnch to Uri, whence it continues along the Jhelam valley till it gradually flattens out and disappears above Muzafarábád: this line does not expose to view any rocks of

the Subáthu group. To the north-east of Púnch, however, a minor anticlinal axis exhibits a small core of nummulitic limestone in its centre.

In the neighbourhood of Muzafarábád the Subáthu rocks are more extensively developed, as will be seen by the map. They form an isolated mass in the Khágán valley above Bálákot; while to the south of that place they form a band on the western boundary of the tertiary bay running down to Muzafarábád itself, whence, after giving off a tongue which nearly cuts off the Murree rocks of Khágán and the Kishanganga from those of the Jhelam valley, they are continued down into Hazára and Rawál-Pindi, where their calcareous member attains a great development.

In the Muzafarábád district, as elsewhere, the Subáthu group passes gradually upwards by means of various olive and black, sometimes carbonaceous, shales, into the overlying Murree group. In its lower beds, however, it differs very considerably from the Subáthu rocks of the Riạsi district. The basement breccia and pisolitic clays of the latter district have not been detected, and the limestone, in place of occurring in beds of only a few feet in thickness, assumes much greater proportions; there being several hundred feet of strong pure limestone, as in the hills on the right bank of the Jhelam at Muzafarábád itself. At other times, as to the north of Bálákot, the limestone, though attaining great thickness, is not massive, but occurs in thin beds with partings of dark carbonaceous and other shales.

The greater thickness and the more calcareous nature of the Subáthu group as it is traced from east to west, and again in the Muzafarábád district from north to south, furnishes a complete transition from the typical examples of these rocks as developed in

the Simla district, to the somewhat aberrant type of the Punjab, part of which it has been attempted to distinguish under the title of "Hill Nummulitic Limestone."[1]

The nummulites from the Subáthu group in the neighbourhood of Murree have been determined by Mr. W. T. Blanford[2] to be *Nummulites beaumonti* and *N. granulosa*,—species characteristic of the Khirtar, or middle eocene, group of Sind, with which the Subáthu group may accordingly be identified.

It may be added that on the inner border of the Sirmúr zone on the right bank of the Jhelam below Uri, there occur some carbonaceous shales, which may indicate an outcrop of the Subáthu group; as, however, these shales are not absolutely characteristic, and nummulites have not been found in them, these rocks are provisionally classed with the Murree group, and may correspond with the carbonaceous shales already described as occurring in that group lower down the river at Kohála.

General relations of the system.

It now remains to consider the relations of the Sirmúr series to the pre-tertiary rocks of the Middle Mountains, which will involve the general relations of the whole tertiary system.

Throughout nearly the whole of the long interval between the Rávi and the Jhelam valleys at their junction with the older rocks the Sirmúr rocks generally dip at a high angle towards the former, and it might at first sight be supposed that the junction was a faulted one. Seeing, however, that the pre-tertiary rocks also dip to the north-east, and will subsequently be shown to be inverted, and

1 See "Manual," pt. II., p. 511: also paragraph No. 6 of prefatory notice by Mr. Medlicott to article 2 of the XVIIth volume of the "Memoirs."

2 "Memoirs," vol. XVII., p. 69.

bearing in mind the apparent conformity existing between the tertiaries and the older rocks in the inliers of older limestone already described, it appears probable that the junction is really a normal one, the tertiaries having been bent back under the inverted palæozoics. This view was first propounded by the late Dr. Verchére, in the memoir quoted above, who observed the junction of these rocks at Uri, where a good section is shown in the gorge of the Jhelam.

The probable correctness of this interpretation is converted into nearly a certainty by the relations exhibited between the tertiaries and the palæozoics in the tertiary bay to the north of Muzafarábád. In this locality on the Kúnhár river below the village of Khágán, the strata of both ages are placed nearly vertically, with a slight south-westerly dip, the nummulitics overlying the palæozoics, and there appearing to be a strict parallelism between the two series of rocks.

It is difficult to conceive that the junction between tertiary and early mesozoic or palæozoic rocks can be strictly conformable, and it is, therefore, probable that if more extensive sections were visible, some degree of unoonformity or overlap would present itself. An inspection of the map will, indeed, show that such unconformity must almost certainly exist somewhere, since it will be seen that in different places the tertiary rocks are in contact with different horizons of the infra-tertiary rocks, with the same apparent conformity.

It may accordingly be concluded that the rocks of the Sirmúr series were probably deposited upon a denuded surface of older rocks, which, however, had not been far removed from their original horizontal position, and had of course undergone no contortion; or in the words of the authors of the "Manual" that in eocene times in these regions "the Himalayas, *as a region of special disturbance*, had then made no beginning."

Further conclusions to be derived from the system.

A further extension of the conclusions to be derived from the tertiary system may now be taken into consideration. It must be observed in the first place that the Siwalik rocks, from their containing solely the remains of land and freshwater animals, must be entirely of freshwater origin, and that they were probably deposited by rivers, running in the same courses as at present, which are still "engaged in laying down great banks of shingle at the margin of the plains, just like the Siwalik conglomerates; and the thick sandstones and sandy clays of the tertiary series are of just the same type of form and composition as the actual deposits of the great rivers.

"Beds of this character alternate with the upper beds of the Subáthu group; so it seems probable that from early tertiary times the sea has been excluded from the sub-Himalayan region, and that the whole of the sub-Himalayan deposits, above the Subáthu group, are freshwater and fluviatile, and formed on the surface of the land.

"The striking agreement in character between the sub-Himalayan rocks and the actual deposits now in progress of formation from Himalayan debris, at once suggests that the mountain border must have been to some extent defined, and the Himalayan area undergoing denudation, from early tertiary times; and it will be seen from the distribution of the Siwalik conglomerates, that during the later tertiary times, the configuration of the mountains must have been very similar to what it is now."

This conclusion as to the freshwater origin of the greater part of the Murree group is strongly confirmed by the subsequent discovery in them of the palm frond already mentioned. It is, however,

probable from the great extension in this group of fine clays that lagoons, left by the drying up of the nummulitic sea, may have borne a greater part in their deposition than the authors of the "Manual" consider probable. It would also appear from the relations of the rocks of the Murree group to the older rocks in the neighbourhood of Muzafarábád, and on the Chínáb in the Riási district, that the Subáthu group never extended continuously over the whole area, but that it was probably deposited in arms and estuaries of the sea reaching up from the deeper sea which must have prevailed at the same time in the Ráwal-Pindi district; or even, perhaps, in detached salt lakes, like the Caspian, which would be very likely to exist in a region from which the sea was gradually retiring, as must have been the case here in later eocene times.

From these considerations it may be inferred, with a high degree of probability, that the Káj-nág and Pír-Panjál ranges indicate an original boundary line in eocene times, but that it is not certain whether the whole of this line was ever swept by the sea.[1] The Jhelam escaped from this boundary line at Urí, and not improbably made its way directly to the Punjab by way of the Púnch valley, up which the Kotli nummulitics prove that an arm of the sea must once have extended. Similarly the Chínáb probably flowed into another estuary, which may also have received the Bari Tavi. To the north-west the Kúnhár and the Kishanganga rivers opened by separate mouths into a large bay, which probably contained an arm of the sea. In later times these rivers probably flowed through the lower Jhelam valley.

1 The views expressed here must be taken to supersede those given on page 21 of the XVth Volume of the "Records."

These considerations lead to the conclusion that the river valleys of the region of the Middle Mountains occupied the same positions in eocene times as at the present day, but that their courses through the sub-Himalaya have, in some instances, been modified in later times.

From the parallelism of the tertiaries and the older rocks along their line of junction, it would seem that originally the dip of the latter must have been directed towards the plains of India at a low angle. Upon this partially denuded sloping surface the tertiaries must have been deposited with the same general inclination, which in a limited area would appear parallel. Movement in later tertiary times, probably by a lateral thrust, has crushed the tertiaries against the older rocks, and inverted both, but has still preserved their original parallelism of dip.

SECTION B.—The Himalayan Tertiaries.

History; Kargil district; dip; Skirbichan section; Khalsi section; Khalsi fossils; Leh section; Skiu section; Gya section; southern border; Chángchenmo; Drás; Singhe-lá; Bráldu; inferences.

History.

The first record of the existence of nummulitic rocks in the Central Himalaya seems to be one by the late Dr T. Thomson, who, in 1852, obtained nummulites from some part of these regions. At a later date the same fossils were obtained by Dr. Stoliczka,[1] who had previously confused the rocks in which they occur with the palæozoics.

Kargil district.

The great belt of tertiary rocks, from parts of which nummulites have been obtained, commences at the town of Kargil (lat. 34° 68′, long. 76° 13′), and after a short prolongation to the west of the Indus, continues up that valley throughout its course in Káshmír territory, as a narrow band of rocks averaging some twenty miles in width. The greater portion of these rocks are of sedimentary origin, but at or near the southern limits of the two extremities of the belt, large developments of volcanic rocks occur.

At the town of Kargil the lower beds of this series consist of soft grey and brown sandstones, shales, slates, and limestones, with a few bands of coarse conglomerate, resting, with a low and regular

1 "Memoirs," Vol. V., p. 344.

south-easterly dip, upon a denuded surface of crystalline rocks, bosses of which here and there may be observed protruding through the tertiaries. Near the village of Paskím the dip of these rocks has increased to nearly 40°, and the higher beds, which are here well displayed, consist of bright purple and green shales and sandstones, with occasional bands of a yellowish sandy limestone. From the lower beds of these deposits, Mr. Drew has obtained casts of spiral holostomatous gastropods belonging to *Melania*, or some closely allied genus; and some lamellibranchs, which very probably belong to *Unio*, although they have been referred to *Pholadomya* or *Panopœa*.[1] Many of the strata at Kargil are 'cross-bedded,' and from this, and the nature of the fossils in them, it may be inferred that they are of fresh, or at all events of brackish, water origin; the same origin being probable for the whole of the beds in the Kargil district.

Dip.

Looking at the tertiaries as a whole, it may be observed that along the whole of their northerly boundary—a distance of nearly 200 miles—their dip is invariably to the south-west, and that between Kargil and Leh, with an occasional exception, the same direction of dip continues throughout the entire width of the series. For some distance to the west of the latter town this dip seldom exceeds 30° or 40°, and is of remarkable regularity, and free from contortions. To the eastward of Leh these rocks, except along their northern border, have, however, undergone a certain amount of contortion, although in most cases this does not appear to have been so extensive as that to which the older rocks have been subjected.

1 These specimens are now in the Indian Museum.

Section near Skirbichan.

As it has been found impossible to trace the different beds of the Indus tertiaries continuously along the strike, the best general conception of the components of the series can be gained by taking transverse sections at various points. The first of these sections is taken in the neighbourhood of the village of Skirbichan,[1] below the point where the Káshmír and Ladákh road enters the valley of the Indus near Khalsi. In this neighbourhood the gneiss of the Ladákh range forms a denuded escarpment on the right bank of the Indus, with a slope of about 25° towards the Indus, the dip of the beds being in the opposite direction, or towards the north-east; the slope of the escarpment is irregular, and covered with hollows and hillocks. Upon this sloping denuded surface the tertiaries rest in the manner shown in the accompanying woodcut (fig. 6), their dip being slightly less steep than

Fig. 6.—Diagrammatic section of the Indus valley at Skirbichan, showing the relation of the tertiaries to the gneiss.

the general inclination of the surface of the gneiss. From this relation it follows that the lowest beds of the series, which occur near the base of the slope, are cut off higher up by the projecting hillocks of gneiss, while the higher beds extend considerably higher up the slope, with a very marked 'overlap.' Many analagous sections occur

1 Lat. 34° 52′, long. 76° 82′.

in the neighbourhood, and afford proof that the junction between the tertiaries and the crystallines is a normal one, marking the approximate original northerly boundary of the tertiary area. The lower tertiaries at Skirbichan consist chiefly of slaty shales and sandstones, generally greenish or greyish in colour, and marvellously like some of the unmetamorphosed palæozoics to the south of Khalsi. In the neighbourhood of the larger tributary streams flowing from the range to the north, as at Dumkár and Khalsi, the shales and sandstones are replaced by grits and coarse conglomerates, containing pebbles of the crystalline and other pre-tertiary rocks. This conglomerate is of considerable thickness in the above-mentioned streams, and since similar beds occur on most of the larger streams between this part and Leh, and not, as far as can be observed, in the intervals between them, it may be inferred that the present drainage lines existed in early tertiary times.

Khalsi section.

A section from north to south at Khalsi[1] may be taken as a typical example of the tertiaries in this region. The lower beds, as already mentioned, consist either of conglomerates, grits, sandstones, or slaty shales, according to their proximity or distance from the tributary streams; the sandstones not unfrequently exhibiting well-defined ripple marks. These beds are succeeded by orange and brown calcareous sandstones, intermingled with occasional shales. Above these again are green and purple, or dark red, shales; the latter being in great force at Bázgo, higher up the Indus, and quite indistinguishable from the red rocks of the Murree group of the Outer Hills, while the former closely resemble the shales of the Subáthu group of the same region. Between the villages of Khalsi and Nurla (Snulra), on the right bank of the

1 13 miles higher up the river than Skirbichan.

Indus, these brightly coloured shales are overlain by a thick band of coarse, blue, shelly limestone, containing numerous small disks, which may be partially altered nummulites or alveolinœ, though their characteristic structure is not apparent. This limestone is overlain by several feet of a coarse calcareous conglomerate, containing pebbles of the same limestone, and again succeeded by shales and slates, generally of a grey colour. The further extension of this section is interfered with by the great mass of volcanic rocks occurring to the south of Khalsi, but the portion exhibited may be tabulated as follows, viz.:—

1. Greyish shales and slates.
2. Coarse calcareous conglomerate.
3. Shelly limestone.
4. Purple and green shales and sandstones.
5. Orange and brown calcareous sandstones and shales.
6. Grey and brown slaty shales, sandstones (often ripple-marked), grits, or conglomerates.

Fossils from Khalsi limestone.

Besides the above-mentioned disks, a species of *Turbo* has been obtained by the writer from the Khalsi limestones, and Lieut.-Colonel Godwin Austen has sent to the Indian Museum fragments of this shelly limestone, obtained on the left bank of the Indus where the Káshmír road joins the valley, containing obscure fossils. These fossils are considered by Colonel Godwin Austen to belong to *Hippurites*, and to some cephalopodous form which may be *Hamites*. The impressions are, however, so obscure and imperfect, that the determination can scarcely be considered to be free from a considerable element of doubt. If the determination be, however, correct, it indicates the remarkable fact of the persistence of characteristic European cretaceous genera into the

tertiary. There are, however, indications in other parts of India[1] of a commingling of the tertiary and cretaceous faunas, and, therefore, the anomaly is not so great as it might at first appear. Still, assuming of course that the determination is correct, the occurrence of cretaceous fossils so high up in the tertiary series is very remarkable, the more especially that the tertiary and cretaceous series in the inner Himalaya have no connection with one another, as far as is known.

Section near Leh.

Above Khalsi the section of the lower tertiaries differs considerably from the foregoing, although the sections of the series are not so well exhibited as might be desired. On the tributary stream flowing into the Indus at the village of Saspúl, some thirty miles below the town of Leh, the northern boundary of the tertiaries is nearly coincident with the upper Káshmír and Ladákh road, which runs at some distance to the northward of the Indus, through the village of Himis-Shukpa. On this line the lower tertiaries, resting on the gneiss, and dipping to the south-west at an angle of about 25°, consist of very soft and crumbly pale-brown and yellow sandstones, with frequent cross-bedding. In these sandstones are embedded great numbers of more or less rounded boulders of the gneiss, often attaining a diameter of several feet. Some of the isolated boulders show the beds of the sandstone bending down below them; and the polishing and smoothing of some of the others seems suggestive of ice-action. These soft sandstones are overlain by green shales, and the beds marked No 4 in the Khalsi section. It is difficult to imagine how these gneissic boulders could have attained their present position in the midst of soft sandy strata, without the aid of ice as a means of

1 See W. T. Blanford, "Geology of Western Sind," ("Memoirs," vol. XVII.), pp. 35-6.

transport; but as the evidence in favour of this is by no means conclusive, the confirmation or refutation of this suggestion must be left for future observers.

The Indus valley has a very characteristic section in this neighbourhood, as is shown in the accompanying woodcut (fig. 7). Thus

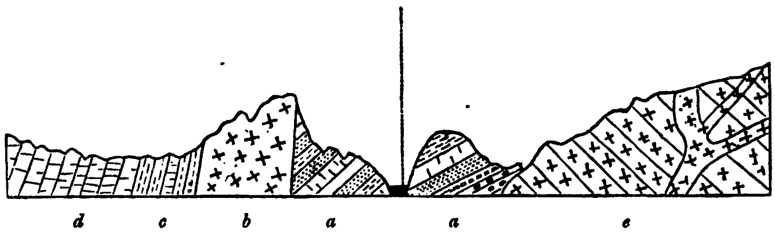


FIG. 7.—Diagrammatic section of the Indus valley west of Saspúl. *a* sedimentary tertiaries with conglomerates at base; *b* tertiary traps; *c* Kulíng series; *d* supra-Kulíng series; *e* gneiss with granite veins.

at the foot of the gneissic range there is a valley formed by the denudation of the above-mentioned soft sandstone conglomerates at the base of the tertiaries, along which runs the upper high-road; then there is another bold ridge, formed by the harder shaly tertiaries; then the deep gorge of the Indus, from which there is a gradual ascent on the opposite side, across the tertiary beds, to lofty crags formed by the hard tertiary traps. These features are very constant for many miles.

Nearer Leh itself, in the neighbourhood of the village of Ling[1] the soft sandstone with gneiss boulders is absent, and the lowest beds consist of soft parti-coloured shales and sandstones, with occasional small nests of selenite, and bands of a very hard and compact

1 Not marked on the accompanying map.

buffish-grey limestone, in which there occur numerous well-preserved specimens of a large species of *Estheria*, indicating the prevalence of brackish, or freshwater, conditions. These beds are overlain by the purple shales, like the red rocks of the Sirmúr series of the Outer Hills.

At Nimu (Snimo) soft arenaceous beds with embedded gneiss boulders occur, which are very slightly inclined, but seem, from their similarity, to correspond with the lower tertiaries of Saspúl. Their relations to the higher tertiaries are not, however, well exhibited, and to the south-east they are concealed by a later boulder deposit, which also covers the base of the tertiary series near Leh, where the latter has been much denuded away along the Indus valley.

Above Leh, on the right bank of the Indus, near the village of Upshi, a strong and consolidated gneissic conglomerate occurs in force low down in the tertiary series, and is underlain along the bed of the Indus by soft gravels, conglomerates, sandstones, and clays, the whole having a dip of about 15° to the south-west. The conglomerate contains pebbles of a lava much resembling that on the south of the tertiary zone, some of which must, therefore, be probably of pre-eocene age. The lowest conglomerate also contains pebbles of the carboniferous and triassic rocks of this neighbourhood; and some of the gneiss boulders in the sandstones are two or three feet in length. From the softness of most of these rocks they have been extensively denuded away, and only scattered patches are visible here and in the bed of the Indus protruding through the alluvial formations.

Section from Phayang to Skiu.

The next section extends from the village of Phayang (Phay) on the right bank of the Indus, a short distance below Leh, to Skiu (Kio) on the Markha river, a tributary of the Zánskár river. On this line the whole of the lower tertiaries between the Ladákh range and Phayang have been removed by denudation; the lowest beds exposed at the latter place consisting of brown and green sandstones, alternating with coarse grits and conglomerates: the sandstones are frequently distinctly rippled, and the pebbles in the conglomerate consist mainly of gneiss, while the grits are composed of coarse granitic sand exactly resembling that now found in the bed of the Indus. Pebbles of gneiss of upwards of five inches in diameter occur in the series at a distance of six or seven miles from their probable source in the Ladákh range. These beds, with several flexures, continue as far as the village of Rambák,[1] where they are succeeded by purple and green shales, and then by similar shales interstratified with sandstones; these beds probably corresponding with the beds marked No. 4 in the Khalsi section. From this point and thence across the Shingo-lá[2] to a few miles above Skiu there is a rolling series of variously coloured slates, shales, and sandstones, with thin bands of blue limestone. Many of the grey shales and limestones are crowded with nummulites, which were determined by Dr. Stoliczka to be *Nummulites exponens* and *N. raymondi*.[3] A species of *Conus*, and other nummulitic fossils have also been obtained from these beds. It is probable that the nummuliferous calcareous beds correspond to the shelly limestone marked No. 3 in the Khalsi section; they are, in any case, high up in the series. Pebbles of the same limestone, full

1 Not marked on the map.

2 Marked on map as "Pass, 16,211": it is sometimes called the Rambák-lá.

3 "Memoirs," vol. V., p. 344.

of nummulites are to be found in great numbers lying on the banks of the Indus at the village of Nimu, opposite the opening of the Zánskár river, by which they have been carried down; but undoubted nummulites have not been obtained from the Indus valley itself to the westward of the Zánskár river.

On the southern side of the Shingo-lá the rocks are much folded, but the flexures are regular and open. At a distance of some two miles above Skiu the nummuliferous beds are overlain by several hundred feet of nearly vertical strata of conglomerate, which locally on the same line contains numerous pebbles of the nummulitic limestone. The conglomeritic beds are succeeded by purple and green shales, sandstones, etc., of a few hundred feet in thickness, which are themselves nearly vertical, and are succeeded by nearly vertical pre-tertiary strata near Skiu itself, which have a slight south-westerly underlie, and preserve an approximate parallelism to the tertiaries.

Gya valley section.

The next section is taken in the reverse direction of the former, running from the upper part of the Gya (Gía) valley to Upshi on the Indus,—some thirty-five miles above Leh. At its southerly boundary on the Gya river the tertiary series is considerably rolled and bent and apparently overlies nearly vertical pre-tertiary strata which have been in many places much contorted. The lowest tertiary beds exposed on the south consist of green and purple shales, with frequent cross-bedding, and showing some indications of unconformity, which, however, is not confirmed by adjacent sections. Upon these shales rest the higher conglomerates of the previous section, which can be traced continuously along the southern border of the tertiary zone from Skiu to the Gya river. These conglomerates are several hundred feet in thickness, and apparently lie in a synclinal: they

contain pebbles both of the tertiary trap, of nummulitic limestone, and of older rocks. Further down the river these upper conglomerates are underlain by a great thickness of green and purplish-red shales, sand-stones, grits, and thin beds of conglomerate. At the village of Miru (to the north-west of Miru station) these highly coloured shales are again underlain by a considerable thickness of what appears to be a lower conglomerate, or breccia, composed of debris of gneissic, mesozoic, and tertiary rocks: this conglomerate has acquired a kind of false slaty cleavage, splitting readily in planes parallel to the bedding, completely through the pebbles. Below this conglomerate there is an anticlinal axis in beds of brown and green crumbly shales and greenish sandstones. These are again overlain towards the Indus valley by the coloured sandstones and shales, apparently without the intervention of the Miru conglomerates. The sandstone and shale group apparently forms a synclinal, and is underlain by a hardened coarse gneissic conglomerate, several hundred feet in thickness, which is again underlain by the softer strata of the bed of the Indus noticed in the preceding section.

At the very base of the Miru anticlinal there occur on the left bank of the river certain dark-coloured and frequently carbonaceous shales, alternating with bands of quartzite, which cannot be distinguished from the older rocks to the south of the tertiary zone, and are probably the same. They present an apparent parallelism to the tertiaries, and much resemble some of them lithologically: a similar resemblance in another district between the older and tertiary rocks will be noticed subsequently.

A certain amount of difficulty presents itself in the interpretation of the foregoing sections, since, as will be gathered from the descriptions, the sections are not symmetrical; high beds, which are

not observable on the northern side, being in contact with the older rocks on the south. This apparent anomaly must of course be explained either by the southerly tertiary border being a faulted one, or by the lower beds on the southern side being concealed by the 'overlap' of the higher. As there is no evidence in favour of the former view, but on the contrary such evidence as there is is against it, the latter view is more probably the true one. In the accompanying diagrammatic section (fig. 8) this relation of the tertiaries is

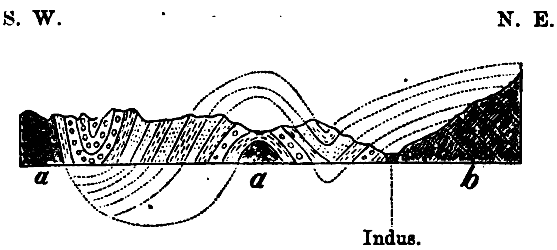


Fig. 8.—Diagrammatic section along the Gya river: tertiaries light, older rocks shaded: a, Kuling (carboniferous) series; b, gneiss.

attempted to be explained. The lower tertiaries of the northern side of the Indus valley are seen on the south to have been overlapped, and hidden from view by the higher beds, which have been subsequently crushed into a synclinal. Whether these higher southerly beds ever extended to the north, above the dotted lines in the diagram, may be considered doubtful, but it is very probable that they did not. On this supposition it is probable that after the lower tertiaries had been deposited continuously across the whole area, the northern side of this area was upheaved, and the higher beds deposited along a narrow valley on the southern side only, from which the sea, or estuary, gradually retired. This explanation is in harmony with the evidences of contemporary denudation afforded by the higher tertiary conglomerates, which contain pebbles of the subjacent nummulitic limestone. It may be added that if the diagram

represents at all a near approximation to the true relations of the rocks, it will follow that the tertiaries are not in perfect conformity with the carboniferous rocks: this question will, however, be further alluded to below.

Southern border of tertiaries.

It now remains to consider more fully the southern tertiary boundary, and the large series of volcanic rocks met with along this line. At the north-western extremity of the tertiary zone the purple shales of Páskim are overlain by a great mass of basaltic trap, or lava, which in this region consists of greenish anamesite, weathering to a pale brown colour. Although there is no visible instance of the intrusion of the trap into the beds of the sedimentary rocks, yet the relations of the two is such as to indicate that the trap is the newer rock. It has, however, been already shown that trap pebbles are contained in the higher tertiaries to the south-east, and it may, therefore, be pretty safely inferred that the emission of the trap took place during some part of the time of the deposition of the tertiaries.

To the south of Páskim the traps may be traced continuously to Shargol, their western boundary running south-south-eastward of that place: the width of the band of trap is here as much as ten miles. At Shargol itself, to the south of the main mass of trap, and extending as far as the village of Mulbekh (Mulbeck), there occurs an outlying band of the tertiary sedimentaries, consisting of soft yellow calcareous sandstones, and the characteristic polychroic shales. The rocks of this band are much mixed up with the trap, and in many places within the trappean area masses of altered sedimentary rocks may be observed, which are probably remnants of the sedimentary tertiaries which probably once extended continuously over the whole area, but which have been broken up and altered by the

eruption of the volcanic rocks. From Shargol the southern boundary of the volcanic rocks runs a little north of Mulbeck, and thence north of the Káshmír and Ladákh road. In the neighbourhood of Lámayúru, the trap is much involved with palæozoic rocks, which will be subsequently referred to. To the eastward of the latter place the southern boundary runs close to the village of Wánla. From Páskim the northern boundary of the volcanic rocks runs for some miles in an easterly direction, then bends to the south-east until it impinges on the Indus at Khalsi, from which point it again leaves that river and forms the craggy ridge on the left bank, gradually dying out among the sedimentaries to the westward of the Zánskár river.

The trap in the above-mentioned area has been described as composed of fine-grained anamesites, greenstones, basalts, serpentines, and a few amygdaloids, and, according to Dr. Stoliczka, of gabbro and diallage-rocks.[1] No porphyritic trap occurs, and when worn most of the pebbles acquire a dark-brown glaze.

In consequence of the disappearance of these traps to the westward of the Zánskár river, the main mass of the sedimentary tertiaries here comes into direct contact with the carboniferous rocks forming the southern boundary of the whole tertiary area. The relations of the two rock-systems have been already touched upon; but it may be added that between Skiu and the Zánskár river the tertiaries, with a low northerly dip, appear to rest unconformably upon the carboniferous rocks, with overlap, and show bosses of the former protruding through them.

1 Dr. Stoliczka, on the ground of particular volcanic rocks being confined to particular geological horizons, would not admit that these rocks were basaltic.

To the south-eastward of Skiu the southern tertiary boundary runs near the right bank of the Markha river, crosses the Ladákh and Kulu road at Látho, and then continues to the south of the Indus as far as the limits of Káshmír territory, its easterly limit being unknown. In the valley of the Markha along this boundary line, numerous small masses of trap are met with, which is generally of a more crystalline structure than the trap to the westward of the Zánskár river; and it is probably pebbles of this trap which are included in the higher tertiary conglomerates. In places, as on the upper Gya river, this trap has burst through the pre-tertiary rocks, and frequently has included in itself masses of the latter crowded with crinoids. To the south-east of the Gya river the band of carboniferous rocks dies out, and the tertiaries on both their borders are in direct contact with the older crystallines. From a little to the westward of the Púga river to the extreme easterly limit of Káshmír territory, an irregularly wedge-shaped mass of the trap separates the sedimentary tertiaries from the older crystallines; and it is near the southern border of this trap that the extensive mineral deposits of the Púga valley chiefly occur.[1]

Along the whole of their southern border to the eastward of the Zánskár river, the tertiaries have been much disturbed and not unfrequently inverted, while their degree of alteration is frequently so great that, on the Gya river, they were at first mistaken by Dr. Stoliczka for the palæozoic rocks.

Reputed tertiaries in the Chángchenmo valley.

In his notes on the journey to Yarkand, Dr. Stoliczka[2] makes the following remarks on certain rocks in the Chángchenmo valley near Kyam (Kium). "Here

1 See the chapter on Economic Geology.
2 "Records," Vol. VII., p. 15.

there are on the left [? right] bank of the river some remarkably recent looking sandstones and conglomerates, dipping at an angle of 45° to north by east, and at the foot of these beds rise the hot springs of Kium. I think it probable that this conglomerate has eastward a connection with the eocene deposits, which occur at the western end of the Pángkong lake, and in the Indus valley south of it." With regard to the latter part of this passage, the present writer has been unable to identify any older tertiary deposits in the neighbourhood of the Pángkong lake, neither are any recorded by Mr. Drew. At the time of his visit to the Chángchenmo valley, in 1879, the present writer was unacquainted with the foregoing observations of Dr. Stoliczka, in reference to the occurrence of eocene strata in that district, and his attention was not, therefore, directed to the point. Near Kyam, however, where the underlying rocks are in great part concealed by alluvial deposits, a conglomerate was observed, which closely resembled the tertiary conglomerate of Miru, in the Gya valley, already noticed. This conglomerate appeared to be underlying the mesozoic dolomites which form the cliffs on the right bank of the river, but this relation may be explained by inversion.

In a note to the writer Colonel Godwin Austen records the occurrence of modern-looking shales, sandstones, and conglomerates in this part of the Chángchenmo valley, and mentions that they are well displayed under Kiepsang station, to the north of the Chángchenmo river, where they rest on the palæozoic slates. These observations all point to the probability of some representatives of the Indus valley tertiaries occurring in the Chángchenmo valley, but it remains for future geologists who may visit these dreary and inhospitable regions, to indicate their correct distribution, and their relations

to the older rocks. The patches of tertiary rocks coloured on the map in the Chángchenmo valley are only approximately placed.

Reputed tertiaries in the Drás valley.

In the Drás valley there occur certain orange and red clays, mingled with a conglomerate or breccia, exactly resembling in petrological characters the tertiaries of the Kargil district, Near the village of Walmio[1] this conglomerate contains fragments of a dolomite, which appears to be the same as that of the mesozoic rocks;[2] and in the Marpo ravine there occurs a serpentine indistinguishable from that of Páskim.[3] These rocks appear to overlie the palæozoics of Drás, but the two (if they be distinct), are so intimately blended together, and resemble one another so closely, that, as in the instance of Shargol, it is almost impossible to distinguish them satisfactorily. Near Waturgu the presumed tertiary rocks are in close relation with the carboniferous rocks, and appear to be uncomformable to them. If these rocks are really tertiary, their association with a trap like that of the Indus valley is a very remarkable fact. It is not improbable that some of the same rocks may occur to the west of Drás, on the road to Tilel, but the whole question is one of great doubt and perplexity.

Reputed tertiaries in Zánskár.

In the year 1853, M.M. D'Archiac and Haime described in their great work on the nummulitic fossils of India,[4] quoted in the introductory chapter, specimens of *Nummulites raymondi* which had been brought, by Dr. T. Thomson, from Ladákh. The fossils are said to have been obtained from

1 Not marked on the accompanying map.

2 Very similar rocks have, however, been noticed in the palæozoic conglomerate of other districts.

3 It is possible that this may belong to the palæozoic traps.

4 Page 176.

the Singhe-(Singhi) lá, on the road between Khalsi on the Indus, and Padam in Zánskár.[1] The majority of the rocks on the Singhe-lá consist of dolomites, limestones, and slates of mesozoic age, and as tertiary rocks have not been detected among them, the reputed origin of these nummulites must be regarded as open to a very strong element of doubt. It has been suggested that they might possibly have been obtained from the Shingo—or Singhe-lá, between Leh and Skiu; but as Dr. Thomson did not apparently traverse this route, it seems doubtful if this solution of the difficulty can be admitted.

Undetermined rocks in upper Baltistán.

On the Bráldu tributary of the Shigar river in Baltistán, to the north-west of the village of Hoto, there occurs a small patch of rocks (blank on the map) quite different from any in the immediate neighbourhood, and apparently faulted down between the gneiss cliffs bounding the valley, though their position may be due merely to original unconformity. These rocks consist of crumbly red, and carbonaceous shales, and yellow calcareous sandstones; and it is possible that they may be the same as the tertiaries of the Indus valley, to which they present a very considerable resemblance.

Trap outlier in Zánskár.

In central Zánskár, to the south-west of Khalsi, there occurs a large outflow of coarsely crystalline trap, occurring apparently in the midst of mesozoic rocks, and similar to the trap within the tertiary area of the Indus to the eastward of the Zánskár river; it forms the peaks numbered D. 24 and D. 25 in the Indian atlas. From the inaccessible nature of the

1 The pass is marked on the accompanying map Singhe Pass and is situated on the watershed of the Zánskár river due south of Khalsi: the height of the pass is 16,600 feet.

locality where this trap occurs, its surrounding rocks have not been examined. There is, however, some evidence to show that it is older than the crypto-crystalline trap of Páskim. This evidence is as follows;—Close to the village of Wánla, to the south-east of Lámayúru, there occurs a wide dyke of the Páskim trap running among the pre-tertiary rocks. On the south side of this dyke, between it and the latter rocks, there is wedged in a nearly vertical bed of coarse conglomerate, a good deal altered by the trap, and containing pebbles of mesozoic limestone, and of crystalline trap similar to that forming the above-mentioned peaks in central Zánskár. It is not improbable that this conglomerate may represent an outlier of the higher tertiary conglomerate of the Gya section, in which case it proves the Zánskár trap to be newer than any of the sedimentary tertiary rocks.

Inferences to be drawn from the tertiaries.

Having now indicated the general distribution of the Himalayan tertiaries, it remains to be considered what indications may be drawn from their mode of occurrence, and the facts known regarding them.

With regard to the question of age, the occurrence of *Nummulites raymondi* in the Ladákh tertiaries, and in the Khirtar group of Sind,[1] identifies the former—or rather their higher zone in which the nummulites occur—as of middle eocene age, and the equivalent in part to the Subáthu group of the Sub-Himalaya. The whole series may probably be roughly classed as of eocene age, although it is quite possible that its higher beds may extend upwards into the miocene epoch, and partially represent the Murree group of the Sub-Himalaya. The possibility of the survival of cretaceous forms into the eocene has been already alluded to.

1 "Memoirs," Vol. XVII., p. 48.

The question of the mode of deposition of the tertiary series may give rise to more discussion. The occurrence of nummulites proves that many of the higher beds are of marine origin, but indications of brackish conditions are suggested by the occurrence of an *Estheria* in the lower beds near Leh, while unmistakeable lacustrine, or estuarine, conditions are indicated by the mollusca found in the lower beds of the north-western extremity of the area. The great resemblance of the purplish-red shales of the Indus valley to the rocks of the Murree group, which are considered to be mainly of freshwater origin, would at first sight seem to indicate that the Indus rocks had a similar origin; but when it is remembered that the Murree rocks frequently pass without change of character into undoubted marine deposits, there will be no difficulty in accepting the view that the red rocks of the Indus valley may be in great part of marine origin. It has been suggested that the great petrological similarity between the Indus valley and the Murree rocks indicates that they were deposited in different parts of the same basin; but a more probable view may rather be that the similarity in the composition of the rocks (whether metamorphosed or not) from whose detrition these different tertiary beds have been derived, has conduced to the similarity in the petrological condition of the latter, though the one may have been chiefly of marine, and the other of lacustrine or fluviatile origin.

It has been observed, in the course of the foregoing descriptions that the present limits of the tertiary rocks of the Indus valley indicate, in general, the approximately original limits of these deposits, and at the extreme north-western limit of the area at Kargil the evidences for this original limit are particularly well marked. This view was first advanced by Dr. Stoliczka, who remarked that the

tertiary boundary at Kargil was the extreme western limit of these beds, and that they had "been formed in a kind of narrow bay of the Tertiary sea, which covered Northern and Eastern Tibet." In previous memoirs the present writer, while considering it probable that the Indus tertiaries had been deposited as Dr. Stoliczka suggested in a narrow arm of the sea, yet thought it probable that this arm communicated with the ocean to the westward, in place of to the eastward. The departure of the deposits from the Indus valley east of Kargil, their abrupt termination at the latter place, the total absence of any similar deposits in the Indus valley below the present tertiary boundary, and the existence of nummulitic rocks in the lower Brámapútra valley at the Khási hills and other places in the more easterly Himalaya, are, however, all points strongly in favour of the correctness of Dr. Stoliczka's view, and against the other. The former view, moreover, accords well with the occurrence of lacustrine, or estuarine, deposits at the north-western limit of the gulf at Kargil, which would be difficult to explain on the other hypothesis. The acceptation of Dr. Stoliczka's view will, however, necessarily entail the conclusion that the main drainage lines of this part of Ladákh were in eocene times in the reverse direction to their present one, or in other words, that the upper Indus probably drained into the valley of the Brámapútra. Seeing, however, the enormous movements to which the tertiary series of the Indus valley has been subjected, it is quite possible that this may have been the case, and that the lower Indus in post-eocene times cut back the upper part of its valley so as to tap the upper valley of the Brámapútra.

It has already been shown that there is good evidence for considering the northern and north-eastern limits of the tertiary area of the Indus valley as an eocene shore-line, but there is some reason

to doubt whether the whole of the present southerly tertiary boundary was also a shore-line. There is firstly the case of the supposed tertiaries in the Drás valley which, if rightly determined, would indicate that a narrow tertiary gulf ran from somewhere near Shargol in that direction. There is, secondly, the enormous height to which the tertiaries in the neighbourhood of Leh have been elevated, reaching in Kanri, or Stok peak, nearly opposite Leh itself, to the height of 21,000 feet, which is greater than the height of any of the mountains immediately to the south of the tertiary boundary. This indicates such enormous changes in the relations of the rocks on this side of the tertiary area, that although in places there is evidence to locate the original shore-line somewhere near the present tertiary boundary, yet there is no reason why in other places the original boundary should not have run out far to the south, and have included the Singhe-lá (where Dr. Thomson's nummulites are said to have been obtained), which may then have been at the sea-level.

The presumed tertiaries of the Chángchenmo valley must probably have been deposited in a separate arm of the sea, communicating, as Dr. Stoliczka has suggested, to the eastward with the old Indus valley gulf.

The last point for consideration is the bearing of the Indus valley tertiaries on the elevation of the Himalaya. In previous papers, from the regularity of the dip of the latter, the present writer has been inclined to consider that in the central Himalaya the great period of crushing was of pre-eocene date, but further observations tend more and more to disprove this view. The great regularity of the dip of the Indus tertiaries, although at

first sight seeming to indicate their deposition after the great period of Himalayan crush, is not really much more regular than the dip of the Murree rocks in the Outer Hills, which have already been shown to have been deposited before the same great epoch; and is counterbalanced by the parallelism existing in several places in Ladákh between the tertiary and older rocks, which can only be explained by the latter having been in eocene times still approximately horizontal, although extensively denuded. The frequent inversion of the older rocks on to the tertiaries, and (if the determination be correct) the intimate blending of the tertiary and palæozoic rocks in the Drás valley can hardly be explained in any other way. Further, it is perfectly evident that the upper Indus valley must have been raised from the sea level to its present enormous elevation entirely since the eocene period, and it is inconceivable that such an immense amount of elevation, which, in all probability, was caused through a tremendous lateral pressure which has inverted all the older rocks of the Outer Hills, could have taken place without an enormous amount of contortion and crushing of the rocks which were raised by it. Why, as is certainly the case both in the Outer Hills and in the Indus valley, the tertiaries should have frequently not participated so extensively in this great crush, it is difficult to explain. It may be, however, that their position at the top of the series has to some extent protected them from injury, and only thrown them into large folds, in place of twisting and bending them in the manner which is so common in the subjacent rocks.

Chapter VI.—THE ZÁNSKÁR SYSTEM, OR MESOZOIC AND CARBONIFEROUS ROCKS.

Distribution of rocks; classification of rock-systems; Káshmír basin, southern division; Káshmír basin, northern division; outliers in the northern division of the Káshmír basin; fossils of the Káshmír basin.

Distribution of rocks.

An inspection of the accompanying map will show that the palæozoic and mesozoic rocks overlying the great crystalline foundation of the north-western Himalaya occupy a series of more or less well-defined depressions, or basins,[1] between the great crystalline areas. The best defined of these basins may be termed the Zánskár basin: this is continuous to the south-east with the Spiti basin, the two being collectively termed the Zánskár-Spiti basin: the former, which alone comes within the province of this memoir, comprehends the great trough of palæozoic and mesozoic rocks lying between the Zánskár and the Ladákh ranges. To the north-west this basin is connected by a narrow band of palæozoic rocks, with the second great basin of palæozoic and mesozoic rocks, which may be termed the Káshmír basin: this is bounded on the north by the great crystalline area of Baltistán, and on the south by the crystalline, or gneissic, central axis of the Panjál range: it contains two minor basins of mesozoic rocks, one occurring in the valley of Káshmír proper, and the other embracing portions of the Kishanganga, Drás, and Wardwan valleys: a small gneissic axis divides the north-westerly

[1] It is scarcely necessary to remind the reader that the term 'basin' has very different significations when applied to a river valley, and to an area of rocks.

extremities of these minor basins. Towards the south-east the Káshmír basin is connected by an isthmus of palæozoic rocks with a third basin, which may be called the Chamba basin, and is bounded to the north-west by the Zánskár range, and in its lower part to the south-west by the crystalline axis of the Dhauladhár range and its trans-Rávi extension: the centre of this basin has not yet been fully examined, but its development of mesozoic rocks is certainly much less extensive that that of either of the other basins. By the sudden diminution in width of the crystalline axis of the Dhauladhár range at the valley of the Rávi, the palæozoic rocks of the Chamba basin become almost continuous with those of what, for the sake of convenience, may be termed the basin of the Outer Hills, with which may be included the Khágán valley.[1] The latter area is bounded to the north-east firstly by the crystallines of the Dhauladhár range and its north-westerly trans-Rávi extension, as far as southern Bhadarwáh, beyond which there is a tract of geologically unexplored country. Still further to the north-west the boundary is formed by the gneiss of the Panjál range. Only occasional outcrops of the proper rocks of this basin are observed along its central line, the majority of them, as well as the southern border of the basin, being deeply buried beneath the tertiary rocks of the Sub-Himalaya, and the alluvium of the plains of the Punjab. The few remnants of the older rocks of the central part of this basin which are visible, show that there must be an extensive development of mesozoic rocks in its centre. Near the north-western limits of the area treated of in this memoir, by the complete dying out of all the crystalline axes of the Himalaya proper, the so-called basin of the Outer Hills is brought into immediate connection with the Káshmír basin.

1 It must be borne in mind that this basin is not co-extensive with the area defined as the region of the Outer Hills.

An imperfectly explored fifth basin, probably containing a very large development of mesozoic rocks, exists to the north-west of the Ladákh range, which may be termed the Chángchenmo and Kárákoram basin: while a sixth basin, which may originally have been a continuation of the Zánskár basin, occurs in upper Baltistán, and may be termed the Baltistán basin.

The former extension of the Káshmír basin over a part of the great crystalline area to the northward is indicated by the occurrence of certain metamorphosed mesozoic rocks to the north-west of Gurez; and various minor developments of palæozoic rocks, frequently blended with the older crystalline rocks, occur within the great crystalline, or gneissic, areas, which will be alluded to in the description of the rocks themselves.

In the following descriptions the rocks of these different basins will be considered separately. The intimate relationship existing between the mesozoic and the carboniferous rocks renders it convenient to treat collectively of these in the first place, while the older palæozoics will be considered subsequently.

Classification of rock-series.

Before proceeding to describe what is known of the mesozoic and carboniferous rocks of these basins, it is necessary to make some introductory remarks regarding the whole rock-series and the different minor groups into which this series is divided, and also regarding the names by which they will be designated.

In his original memoir on the geology of the western Himalaya Dr. Stoliczka determined,[1] mainly upon sound fossil evidence, the following rock-groups as occurring in the Spiti valley, which, as will

1 "Memoirs," vol. V., p. 135, *et seq.*

be seen from the map, lies on the axis of the Zánskár basin, of which, as already said, it is really the south-easterly continuation. In a subsequent paper[1] some slight modifications of the original list were given, and this amended list is the one given here:—

1.	Chikkim beds	Cretaceous
2.	Gieumal sandstone	Upper jura
3.	Spiti shales	Middle ,,
4.	Upper Tágling limestone	Middle lias
5.	Lower ,, ,,	Lower ,,
6.	Pára limestone	Rhætic
7.	Liláng series	Upper trias
8.	Kuling ,,	Carboniferous
9.	Múth ,,	Upper silurian
10.	Bhábeh ,,	Lower ,,

All these names were derived from the Spiti district. In this table it will be observed that strata considered to be of upper triassic age are represented as immediately following others referred to the carboniferous period; Dr. Stoliczka remarking that the Liláng series (or group, as it will be termed in the sequel) "rests immediately above the carboniferous beds, and we have, therefore, the whole Permian (Dyas) and lower Trias (Muschelkalk and Bunter Sandstein) wanting in this part of the Himalaya."[2] In a later paragraph it is added that all traces of the great neocomian series are likewise wanting, although no unconformity is indicated. The same might also have been predicated of the devonian. In spite of this statement as to the total absence of the lower trias it seems probable from subsequent remarks, that Dr. Stoliczka eventually came to the conclusion that certain representatives of the lower trias were to be met with in this part of the Himalaya, which probably belonged to the base of the Liláng group. It was also subsequently observed[3] that the lower Tágling limestone probably corresponded to the Kössen

1 "Memoirs," vol. V., pp. 337-8. 2 *Ibid*, p. 135.
3 *Ibid*, pp. 136—353.

group (*Kösner-schicten*) of the Alps, which some geologists then referred to the lias, and others to the rhætic; the former view being adopted by Dr. Stoliczka. The more modern view appears to be to class the Kössen beds as the top of the rhætic division of the trias,[1] and it, therefore, would seem that the lower Tágling group should be referred to the same period. The more recent observations of Mr. C. L Griesbach in the Húndes district of eastern Tibet[2] have indicated pretty conclusively the existence in that part of the Himalaya of strata corresponding to the lower trias of Europe, thereby confirming Dr. Stolizcka's later conclusion as to the probable existence of similar strata in the more western Himalaya. It is, however, highly probable that in the latter area the development of these strata is much less complete than in the more eastern Himalaya. Certain fossils (*e.g. Ammonites* (*Ptychites*) *batteni*) originally considered by Dr. Stolizcka as belonging to the upper trias (Liláng), are referred by Mr. Griesbach to the upper part of the lower trias (Muschelkalk)

All these great omissions in the rock-series of the north-west Himalaya, as compared with that of Europe, indicate pretty clearly that although it is frequently convenient to refer such formations in the former area as contain fossils characteristic of one or the other of the great European geological systems, to such system, yet that this correlation must be regarded only in the most general sense. It can only imply that the general relative order of the succession of organic forms has been in the main the same, but it cannot be strictly considered, even in the homotaxial sense, that one Himalayan formation is the exact equivalent of its European namesake. Thus since, as will be shown below, in the Káshmír valley no break has

1 Geikie, "Text-Book of Geology," 1882, p. 769 : "Records," vol. XIII., p. 95

2 "Records," vol. XIII., p. 94, *et seq.*

been detected between strata containing fossils characteristic of the lower carboniferous (mountain limestone) of Europe, and the overlying and underlying strata which have respectively been referred to the silurian and the trias, it is quite evident that these cannot really exactly correspond to the European formations after which they are named, but must rather collectively correspond, in a homotaxial sense, to the whole of the silurian, devonian, upper and lower carboniferous, permian, and trias of Europe. Again, the carboniferous of Káshmír, which, as already said, contains fossils characteristic of the lower part of that period, is only a few feet in thickness, and cannot, therefore, contain divisions corresponding to the European divisions of that great system, nor can it represent anything like a period of time corresponding to the enormous carboniferous epoch of Europe.

These considerations all point in the clearest manner to the conclusion that the greatest caution must be exercised in correlating particular minor rock-groups, and still more the narrow palæontological zones of Europe, with what are thought to be their representatives in the Himalaya. Even when the larger terms of the European rock-series are employed, they must be made so elastic as to fit in with the petrological divisions of the rock-systems to which they are transferred, which of course cannot precisely coincide with those of Europe. When further divisions of the rock-systems are required, it is of course perfectly admissable to adopt the distinctions of higher and lower divisions of a European system; but in still smaller divisions it seems, on the whole, preferable to adopt local names, in place of those of the European rock-groups.

Owing to the general paucity of fossil remains in the mesozoic rocks in many districts of the Káshmír territories, it has not generally

been found practicable to recognize the minor groups of Dr. Stoliczka's classification; and since the whole of the rocks from the carboniferous to the cretaceous inclusive, present themselves under the guise of one continuous and homogeneous geological formation, well-characterized by the general prevalence of dolomites and limestones, though the lower beds are generally more shaly, it has been found very convenient to have one general name for the whole of this enormous rock-system, and it is, accordingly, proposed to employ the term Zánskár system, derived from the name of the basin where these rocks are most extensively developed, in this collective sense.

In the table of geological formations, given in the third chapter, the minor divisions of this system are indicated. The upper cretaceous, or Chikkim, division, has hitherto only been recognized within Káshmír territory in the southern extremity of the Zánskár basin, and probably on the extreme north-east frontier (Lokzhung mountains). In the former locality these patches of rocks are separately coloured (*h*) on the map. The middle division for which the provisional name supra-Kuling series is proposed,[1] which is coloured of one uniform tint (*i*) on the map, comprehends the whole of the strata lying between the cretaceous (Chikkim) and the carboniferous (Kuling), and thus corresponds to the jura and trias of other regions.

In previous memoirs the term trias-jura was used for this extensive rock-series; and the term carbo-triassic for the combined lower supra-

1 This term is not free from objection, as it comprehends a far larger series of rocks than the Kuling series; it avoids, however, the introduction of a name which might be confounded with its minor groups.

Kuling and carboniferous series. The application of these terms has, however, been found extremely inconvenient in many cases, since it frequently happens, as in the Káshmír valley, that although beds of the supra-Kuling series are largely developed, it is possible that only those of the trias may be present; and, therefore, a purely local name is preferable. Similarly, in the case of the term "carbo-triassic" for the lower part of the Zánskár system, it was not in all cases possible to say whether triassic rocks were present. For the lower, or carboniferous, division, Dr. Stoliczka's original name of the "Kuling" series may be advantageously retained. Whenever the minor groups of Dr. Stoliczka's classification can be recognized, they may of course retain their original designations. It may be added that while on stratigraphical grounds there is no very good reason for ranking the Chikkim and Kuling series as more important divisions than the groups of the supra-Kuling series, yet the fact that the fossils of these two divisions belong to separate European rock-systems, and are quite distinct from those of the supra-Kuling series, is held to justify this arrangement. No such well-marked divisions exist between the fossils of the jurassic and triassic elements of the supra-Kuling series, which indeed merge into one another.. It will be unnecessary to give here the mineralogical and palæontological characters of the different divisions of the Zánskár system in its typical (Spiti) area as these are fully recorded in Dr. Stoliczka's original memoir already quoted.

With these preliminary remarks, the description of the rocks of the different carboniferous and mesozoic básins may now be undertaken, commencing with those of the southern division of the Káshmír basin.

The rocks of the Zánskár system in the southern division of the Káshmír basin, or those of the valley of Káshmír proper, are first treated of because a well-defined fossil zone exists in the Kuling series of that district, which affords a fixed starting point: for this reason the natural sequence of the rocks is reversed, and the Kuling series described before the supra-Kuling series.

The Káshmír basin; southern division.

Apparently the first definite mention of fossils from the Káshmír valley is contained in a letter from the late Dr. Hugh Falconer to the late Colonel Sir P. T. (then Captain) Cautley, dated January 11th, 1838,[1] wherein it is stated that—"Further, in Cashmeer, I have got from a mountain limestone countless remains of Encrinites, some Corals, and some obscure shells like Terebratulæ." These fossils were evidently obtained either from the Kuling, or from the supra-Kuling series, and most probably from the former. In 1864, there appeared in the "Quarterly Journal" of the Geological Society of London[2] the abstract of an important paper by Colonel (then Captain) Godwin Austin, in which the existence of true carboniferous rocks in Káshmír was definitely proved by the occurrence in them of characteristic fossils, although in an appended note on these fossils by Mr. T. Davidson it was most unfortunately stated that many of the specimens had been obtained from Little Tibet. Two years later the original paper was published *in extenso* in the same journal,[3] with plates of the fossils; the same error being repeated as to the origin of some of the Káshmír carboniferous specimens. In

1 "Palæontological Memoirs of Hugh Falconer," Vol. I., p. 567—Note.

2 Vol. XX., p. 383, *et seq.*

3 Vol. XXII., p. 29, *et seq.*

the same year (1866) another very important paper was published in Calcutta, in the "Journal of the Asiatic Society of Bengal,"[1] by the late Dr. Verchère, in which it was shown that the limestone rocks of the Káshmír valley, instead of being of nummulitic age, as had been previously supposed by some writers, were partly of carboniferous age, and very probably also in part of triassic age. These rocks were subdivided into numerous minor divisions, indicated by local names.

The accompanying map will show the distribution of the Zánskár rocks in the valley of Káshmír. Large masses of these rocks occur at the south-eastern extremity of the valley, extending across the watershed of the Marbal pass, into the drainage basin of the Chínáb; other outliers occur up the Lidar valley, connecting those of the centre of the valley of Káshmír with the northern division of the Káshmír basin. The same rocks are again largely developed in the district of Víhi, to the south-west of Ṣirínagar, and patches occur here and there along the north-western extremity of the valley. Two very small outliers of the middle division occur near the flanks of the Panjál range, appearing through the karewas. As it was in the district of Víhi that these rocks were originally studied, by Messrs. Godwin Austin and Verchère, it may be well to commence their description at the same place.

At the mouth of a narrow gorge situated at the village of Khúnmu[2] (Khoonmoo), on the north-western side of the Víhi valley, some five miles north of Pámpúr, the following series of rocks are

[1] Vol. XXXV., pp. 89, 159.

[2] A large oriental-plane tree (Chúnár) stands at the entrance of this ravine: the village is not marked on the accompanying map.

found overlying the older palæozoic trappean rocks which form the great bulk of the neighbouring mountains.[1]

			Feet.	
Supra-Kuling series.	1.	Limestones	2,200 (?)	
Kuling series.	2.	Bed with shells and *Athyris*	2	43
	3.	Grey limestone	6	
	4.	Limestone with *Productus* and *Spirifer*	3	
	5.	Hard limestone with *Orthoceras*	10	
	6.	Sandy, calcareous, and shaly beds	10	
	7.	Compact quartzite	12	

Another section, also modified from Colonel Godwin Austin's memoir, taken near the village of Barus, on the right bank of the Jhelam, under Wasterwán peak,[2] to the south-east of the Víhi district, is as follows:—

			Feet.	
Supra-Kuling series.	1.	Hard grey compact limestone (denuded)	150 (remaining)	
Kuling series.	2.	Micaceous sandy calcareous beds, with *Spirifer*, *Productus*, and *Chonetes*	60	300
	3.	Calcareous slate or shale	30	
	4.	Compact limestone with obscure fossils	100	
	5.	Shaly limestone with *Fenestella* and *Streptorhynchus*	50	
	6.	Hard compact limestone with *Productus*, *Terebratula*, and *Athyris*	40	
	7.	Compact quartzite	20	

The fossils occurring in the beds marked 2 to 6 of the foregoing section, which have been named the Zewan, or Ziawan beds, by Messrs. Godwin Austen and Verchère, are all of carboniferous forms, and will be further discussed below. They indicate that these beds,

1 This section is adapted from the one given on page 34 of Col. Godwin Austin's memoir: it is possible that some of the lower series may be folded among the higher.

2 Neither this village nor peak are marked on the accompanying map. The latter is situated immediately north of the village of Awántípúr, and forms a conspicuous and well known feature on this side of Káshmír.

with the underlying quartzite, which vary in thickness from a little over forty feet to upwards of three hundred feet, must be referred to the carboniferous, and it will be subsequently shown that they correspond to the Kuling series of Dr. Stoliczka. In the Khúnmu ravine, from some of the limestones marked 1 in the above section, the present writer obtained a specimen of a large triassic species of *Megalodon*, indicating the triassic age of some of these limestones; and from the same great series Colonel Godwin Austen has obtained a cephalopod referred to the genus *Goniatites*, while numerous other fossils, noticed below, were obtained by Dr. Verchère. It is difficult to assign any very fixed boundaries to the Kuling and the supra-Kuling series in this district, as the two pass insensibly one into another. As, however, in the upper Sind valley a characteristic triassic fossil has been found at the base of limestones and dolomites corresponding to No. 1 in the above section, it has been deemed advisable for the present to class as Kuling only such beds as contain characteristic carboniferous fossils, all the higher beds being provisionally referred to the supra-Kuling series.

The Kuling rocks, as already observed, in the Vihi district are generally underlain by massive amygdaloidal and other traps, which frequently, when the bottom quartzitic bed is less strongly developed, pass insensibly upwards into the fossiliferous beds, and it is accordingly probable that some of these traps with their associated shales may really be of carboniferous age. From the remarks already made as to the propriety (when there is no strong palæontological evidence to the contrary) of restricting the European geological terms to accord with the petrological conditions of the rocks of other countries to which they are applied, it will be inferred that it is considered best to confine the lower extent of the Kuling, or carboniferous, to

the proper beds of the fossiliferous series: all the traps in this district are, therefore, referred to the older palæozoics. The carboniferous rocks of Víhi may be traced to the northward into the Arrah valley, to the north-east of Sirínagar, where they bend round to take a north-easterly direction below the survey station of Máhádeo: fossils have, however, not been generally found in the Arrah valley, and the upper boundaries of the Kuling series are consequently given somewhat approximately. The whole series is here inverted on the northern side, the supra-Kuling rocks underlying the Kuling series, and the latter the older palæozoic rocks, which are more generally sedimentary in character. The eastern boundary of this area of Zánskár rocks runs across the western side of the upper Trál valley, thence cutting again into Víhi on the northern side of the peak above Awántípúr (Wastarwán peak). Along this boundary line the characteristic carboniferous fossils are to be found in great abundance, especially on the high ridge to the north-east of Prongám,[1] and also to the south-east of Mandakpál.[1] The Kuling rocks on this side generally consist of black and brown highly carbonaceous shales, cherts, and blue limestones, in varying proportions. The shales when freshly split emit a strong fetid odour, and are frequently crowded with fenestellæ and other fossils. Near Mandakpál the cherty beds often pass into a highly siliceous blue or white rock, closely resembling flint or chalcedony. From south to north along this border the underlying rocks change considerably in character, becoming entirely trappean on Wastarwán peak. The Kuling series, overlain here and there by supra-Kuling beds, may be traced round the north-western flanks of the same peak. On the south side of

[1] These small villages, both on the western side of Víhi, are not marked on the accompanying map, but will be found on the Atlas sheets.

this peak, to the north-west of Awántípúr, there is a small outlier of the Kuling series occupying a spur projecting from the underlying traps, the rocks of which are crowded with the characteristic fossils. The connection existing here between the sedimentary Kuling rocks and the underlying traps is extremely intimate, and fossils are frequently found in juxtaposition with the traps; so that on splitting open the rock it will not unfrequently be found that a fossiliferous layer divides so as to leave one portion adhering to the underlying trap, and the other to the overlying shales. Occasionally the fossils are found entirely in beds which cannot be well distinguished from the traps, though doubtless consisting in part either of contemporaneously altered sedimentary detrital rocks; or of these mingled with ashes. This intimate connection of the Zánskár and Panjál systems will be subsequently referred to, The limestone rocks of Víhi and other parts of the Káshmír valley form a very striking feature in the landscape, their light blue and white tints standing out in marked contrast to the sombre hues of the older slates and traps. The limestones are usually thin-bedded; narrow partings of shale dividing the different layers, and causing the sides of the cliffs of these rocks to present a very characteristic banded appearance, which in Víhi is rendered still more picturesque by the numerous graceful folds and waves into which these strata have been thrown. From the base of cliffs of these rocks in various parts of the south-eastern end of the valley of Káshmír burst the numerous springs of water which form the sources of the Jhelam. The largest of these occur at the villages of Bawán, Islámábád, Achibal, and Vernág. The water is remarkable for its transparency, and frequently gushes out in great volumes: it is generally somewhat higher in temperature than the surface water.

The next development of Zánskár rocks to be noticed occurs in the Lidar valley, where these rocks are to be found at the village of Pailgám, and again lower down half-way between that place and Islámábád. The latter outliers of these rocks commence at the village of Eishmakám, which, though not marked on the accompanying map, is situated on the lower border of the first of the three ellipses of Zánskár rocks marked on the map. A diagrammatic section of the rocks occurring between Islámábád and Pailgám is given in figure 2 of plate III., in order to show the complicated flexures to which they have been subjected, and the amount of denudation which has taken place. The diagram will show that the dip of the whole of the rocks is to the north-east, the compression to which they have been subjected having been so great as to have induced a complete parallelism of dip, and the whole series now forming an isocline.

The Zánskár rocks of Eishmakám occur in three ellipses, situated on the strike of the Víhi rocks, thickest on the line of the river, and gradually dying out on either side. Their relations will be best made clear by a brief description of the whole section from Pailgám to the mouth of the Lidar valley. At Pailgám itself there occur the characteristic thin-bedded limestones and dolomites of the supra-Kuling series, underlain by a thin band of the Kuling shales and limestones in which the characteristic fossils are of not uncommon occurrence: these rocks gradually pass downwards into a great mass of amygdaloidal traps of the Panjál system, which show some signs of stratification in their higher beds, but lower down are extremely massive. Some eight miles down the valley, below the village of Bhatkot,[1] these trappean rocks are underlain by a band of

1 Not far from the spot marked Kotsu on the map.

Kuling rocks with their characteristic fossils; among which the caudal part of a specimen of a trilobite of the genus *Phillipsia*, not improbably identical with *P. semenifera* of the carboniferous of Europe, was obtained in 1880 by the writer. This is the only specimen of a trilobite known from any of the rocks of this district and is represented of the natural size in plate II., figure 5, and enlarged in 5a. These Kuling rocks are in their turn underlain by dark slates and light-coloured quartzites of the Panjál system, and the latter by a band of Kuling rocks, which is followed by the Panjál slates and quartzites. Approaching Eishmakám these Panjál rocks are again underlain by a band of the Kuling shales and calcareous rocks, followed inferiorly by limestones, dolomites, and green and purple shaly slates, some of which are evidently the representatives of the supra-Kuling series, and below which there again occur the rocks of the Kuling series with their characteristic fossils. Below Eishmakám there is once more a series of the sedimentary Panjál rocks, which to the south are inverted upon the rocks of the Zánskár-system of Islámábád. Some further inferences from the Lidar section will be drawn in a subsequent chapter, but it will suffice here to say that the section indicates a vast inversion of a great part of the series coupled with complex folding, the original extent of which is approximately indicated in the accompanying section.

The Zánskár rocks of Pailgám, which on their south and south-western border consist of the Kuling series, overlain by the supra-Kuling series, form a sub-oval-shaped mass, of some eight miles in length, extending up the two branches of the Lidar river. It is probable that the Kuling rocks also occur along the north-eastern border of this oval, since on the eastern branch of the river, on the road to Shísha-Nág, the strata have a northerly strike and a

westerly dip, and the rocks of the Zánskár system are underlain by the traps of the Panjál system. The Kuling series on this line seems, however, to have been obliterated by the traps, as will be shown to be the case elsewhere, and it has consequently been found necessary on the map to place the rocks of the supra-Kuling series in direct contact with the Panjál rocks.

Turning now to the great truncated ellipse of Zánskár rocks occupying the axis of the south-eastern extremity of the valley of Káshmír, it has been already stated that these rocks first occur at Islámábád, where they form the high isolated rock at the back of the town, having a low north-easterly dip, and consisting chiefly of thin-bedded limestones and dolomites with shaly partings. A band of karewa deposit conceals the northern part of these rocks, beyond which they reappear at the village of Bawán, where they are inverted under the older palæozoic rocks of the lower Lidar valley. To the south-east of Bawán the boundary of these rocks runs close to the village of Naubúg (Nowboog), where there is a considerable flexure, and thence across the Marbal pass to a point some six miles on the eastern side, where the writer obtained characteristic Kuling brachiopods in a hard grey shaly slate. At this south-eastern extremity of the ellipse the Kuling rocks, which are here the only representatives of the Zánskár system, are almost indistinguishable from the underlying slaty Panjáls, and would not have been recognized to the eastward of the pass, had it not been for the above-mentioned fossils. Along the inverted Naubúg boundary fossils may here and there be detected in the normal Kuling shales.

Towards the south-west the rocks of the Zánskár system extend as far as the northern flanks of the Pír-Panjál range at Banihál,

whence their boundary probably runs to meet the point to the eastward of the Marbal pass where the above-mentioned fossils were obtained. On the road leading up to the Banihál pass, as far as can be seen through the dense forest which covers the mountain side, the Zánskár rocks consist of dolomites and limestones of the supra-Kuling series, having a south-westerly dip towards the older Panjál rocks; the dip of the latter, as recorded in a section taken some years ago, being in the opposite (north-east) direction. (See plate III., fig. 1.) If this section represent the real relation of the rocks it would seem to indicate that the junction is here a faulted one: it is, however, quite possible that along other parts of this line the junction may be a normal, but an inverted, one, the trappean rocks blending with, and obscuring the Kuling horizon. Further observations are, however, necessary with regard to this relationship.

The rocks in the centre of this great ellipse of the Zánskár system belong mainly to the supra-Kuling series, and are characterized by the prevalence of light-coloured and thin-bedded dolomites and limestones. On the line from the Marbal pass to Ságám, however, there occurs an anticlinal axis, in which the cherts and shales of the Kuling series, crowded with various species of *Productus*, *Spirifer*, and *Fenestella* are well exposed. Owing, however, to the variation in the petrological characters of the beds themselves, as well as the absence of fossils at Ságám itself, the precise boundaries of the Kuling series are difficult to determine, and it is possible that rocks of the Panjál system may be exposed. On the map some rocks of the Kuling series are indicated, on another anticlinal axis, at Sháhábád, but as fossils have not been obtained here it is not impossible that these rocks really belong to the supra-Kuling series; the distinction between the rocks of the two series is, however, very

difficult to determine in this neighbourhood in spots where fossil evidence is not forthcoming.

Passing to the north-western side of the valley, two small outcrops of supra-Kuling limestone appear on the flanks of the Pír-Panjál range at and near the village of Birwa (Biru). These limestones have a low north-easterly dip, and protrude through the karewa formation: they are on the strike of the Sháhábád ellipse, and it is probable they are connected below the karewa formation with lower Zánskár rocks, overlying the older palæozoics of the Panjál range.

On the opposite side of the valley three small patches of Zánskár rocks occur in the neighbourhood of the Walar lake. The first of these is situated at the village of Mánas-Bal, forming the shore of the small lake there, and running in two projections high up on the sides of the adjoining mountains. Near the mouth of the Sind valley these rocks consist of pale-blue banded limestones overlying the blackish amygdaloidal trap, with a north-easterly dip: they extend a little distance to the south of the Safapúr trigonometrical station, to the west of which the trappean rocks again project into the middle of the Zánskár rocks; the latter having a quaquaversal dip around the former. To the south of the lake another small dome-shaped mass of amygdaloidal trap underlies the calcareous rocks. Near this spot, at the village of Kandarbal,[1] the Zánskár rocks consist mainly of nearly pure white thick-bedded dolomitic limestones, which are largely quarried for the manufacture of cement. Remains of crinoids and obscure shells are very common in these rocks, but the only well-preserved fossil that has been obtained from them is part of the shell of a specifically indeterminable *Orthoceras*, which

1 Not marked on the accompanying map.

was collected by Mr. W. Theobald. The Mánas-Bal rocks are much contorted, and are characterized by the usual banded appearance which with their light colour forms a striking contrast to the underlying unstratified traps. These rocks are the same as the supra-Kuling series of other parts of Káshmír, but no traces of the fossiliferous carbonaceous shales and cherts of the underlying Kuling series have hitherto been detected at their base resting upon the traps. The most probable explanation of this apparent anomaly, here and elsewhere, seems to be that the trap, which, from its showing no signs of intrusion into the overlying limestones, must be of contemporaneous origin with the rocks with which it is associated, was outpoured during the deposition of the Kuling series, and has, so to speak, absorbed these deposits, and altered them out of all recognition. On this theory the upper trap here, and in other localities where similar conditions prevail, must really belong to the Zánskár system, but, as already said, it is found more convenient to class the whole of it with the underlying Panjál system.

To the northward of Mánas-Bal another small patch of Zánskár rocks occurs near the village of Hájan, and there are other patches in the neighbourhood which are too small to be shown on the accompanying map. These small patches lead on to the larger mass which occurs at the village of Bandipúr, at the north-western extremity of the Walar lake. At this spot the rocks of the Zánskár system occupy a rudely triangular area on the left bank of the Bandipúr stream; having a low and regular north-easterly dip, or one towards the older rocks. From this dip, and from the fact that there is evidently no inversion of the rocks at Mánas-Bal, it would seem probable that the junction between the Zánskár and Panjál systems is here a disturbed one. The lower beds (assuming the absence of

inversion) consist of cherty sandstones, and blue limestones, with occasional shaly bands, while the higher beds consist of thin-bedded, light-coloured, and frequently dolomitic, limestones: the lowest exposed beds contain numerous crinoids and corals. The greater part of these rocks certainly belong to the supra-Kuling series, but whether the Kuling series may not also be represented at the base of the series must remain uncertain until it be definitely determined whether the beds are in their normal position, or inverted.

At the extreme north-western end of the valley of Káshmír rocks belonging to the Zánskár system are met with at the village of Trigamma. These rocks consist mainly of the usual limestones and dolomites, the former being generally of a dark blue colour, and frequently occurring in beds of some two feet in thickness; they apparently rest in a synclinal of the Panjál rocks; and do not extend across the ridge into the valley of the Kishanganga. The greater part of these rocks certainly belongs to the supra-Kuling series, but on their northerly and easterly borders they are underlain by some greenish and black shaly and slaty beds, mixed with earthy limestones, which must probably be regarded as the representatives of the Kuling series, although fossils have not hitherto been obtained from them. On the western border of the exposure the basement beds are in great part concealed by alluvium and debris.

At various other localities at the north-west of the valley of Káshmír, and in the hills between the latter and the lower Kishanganga valley, several small outliers of the limestones and shales of the Zánskár system are to be met with, whose distribution is sufficiently indicated on the accompanying map, so as not to require description. These rocks in all cases overlie the rocks of the Panjál system, and when largely developed, probably contain

representatives both of the Kuling and the supra-Kuling series; while the smaller outliers probably consist only of the former series. In the absence of fossils, however, the exact discrimination between the rocks of these two series is a matter of considerable difficulty, and the colours on the map must accordingly be considered only as an approximation to the truth. The occurrence of these Zánskár rocks in the tributaries of the lower Kishanganga valley is of considerable importance, since from their proximity to the pre-tertiary limestones and shales of the Outer Hills, which they closely resemble in petrological characters, they afford important evidence in correlating those rocks with the Zánskár system. This point will be further discussed in the sequel; it may, however, be added here that the absence of fossils from the rocks of the Zánskár system in north-western Káshmír and the lower Kishanganga valley serves to bridge over the difference between the fossiliferous Kuling rocks of the same system in south-eastern Káshmír, with the unfossiliferous limestones and shales of the Outer Hills.

The mode of occurrence of the Zánskár rocks in the valley of Káshmír, will lead to the conclusion that this valley is formed on the line of a synclinal axis of newer palæozoic and mesozoic rocks, the original symmetry of which has been partially destroyed by faulting or other movements. It is probable that the area now covered by alluvial and karewa deposits is mainly underlain by the rocks of the Zánskár system.

Northern division of the Káshmír basin.

The northern division of the Zánskár rocks of the Káshmír basin comprehends, as already mentioned, the great mass of rocks extending from Gurez in the north-west, to Drás and Suru in the south-

east: isolated patches of similar rocks occurring in the water-basin of the Kishanganga below Gurez, may be conveniently included in the same division.

An inspection of the map will show that this great area of Zánskár rocks occupies a synclinal depression, bounded in most parts by the Kuling series, and containing nearer the centre the supra-Kuling series. At the point, however, where the area is widest, the centre of it has been pushed up by an anticlinal axis exhibiting the rocks of the Kuling series, and of the underlying Panjál system. The determination of the Kuling series in the whole of this extensive area rests mainly upon relative position, and petrological composition, since its characteristic fossils have hitherto only been obtained in one spot in the upper Wardwan valley.

The best idea of the Zánskar rocks of this area will be gathered from several sections and traverses, taken along the lines of the main roads. The first of these sections is the one exhibited on the high road from Káshmír to Ladákh, which first follows the course of the Sind valley, then crosses the Zojí-lá, and thence leads down the valley of the Drás river to the town of that name. A diagrammatic representation of this section is given in figure 4 of plate III.

In the Sind valley, near the village of Gagangír (Gaggangír), the black and grey slaty shales and sandstones of the Panjál system, with a north-easterly dip, are conformably succeeded by massive dark blue limestones, with some blue and white cherty, and dark shaly beds at their base. These limestones and shales certainly belong to some part of the Zánskár system, and from their succeeding the Pánjál rocks, and being, as far as can be ascertained, continuous with the fossiliferous Kuling rocks of the upper Wardwan valley, they

have been referred to that section of the system. These presumed Kuling rocks continue as far as the base of the lofty ridge running between Gagangír and Thájwáz, which, from bearing the trigonometrical station of Shalián, may be termed the Shalián ridge. This ridge consists mainly of massive amygdaloidal trap; and it appears from the section in the angle above Gagangír that the Kuling rocks dip under these amygdaloidal traps, as is shown in the diagrammatic section. On the northern side of the Shalián ridge, at the commencement of the open mountain valley of Sonámarg, the amygdaloids are overlain by a great thickness of the rocks of the Zánskár system, with a north-easterly dip; at first at a high angle, but which becomes much lower at Sonámarg itself. Immediately above the amygdaloidal traps, and apparently blending with them, there occurs a band of carbonaceous and pyritiferous shales, with blue quartz-veined limestones and cherty rocks. This band, from its close similarity to the Kuling rocks of Wardwan and the Káshmír valley, is inferred to be the same; from which it is concluded that the Shalián ridge represents a concealed anticlinal axis, as will be gathered from the figured section, while the Kuling band at Gagangír represents a compressed synclinal. The difference in the composition of the rocks underlying the Kuling series in different parts of this neighbourhood will be further discussed in the sequel.[1] The Kuling series at Thájwáz is overlain by a great thickness of thin-bedded limestones, dolomites, and shales, with some local inversion, forming the precipitous cliffs on the right bank of the Sonámarg river; crossing the river at that place, and thence running on both sides as far as Báltal, where the road across the Zoji-lá once more travels across the strike of the rocks.

1 It might be supposed that faulting would explain this anomaly, but it will be shown below that this is improbable.

Close to the village of Thájwáz, Dr. Stoliczka obtained from the limestone series a specimen of *Ammonites* (*Ptychites*) *gerardi*[1] (Blanford), a species characteristic of the Liláng group of Spiti. These rocks may, therefore, be referred to some part of the trias, and it is from their close proximity to the band which from its position must probably correspond to the Kuling series of the valley of Káshmír, that the beds immediately above the latter are referred to the trias. In Húndes, the beds in which the above-mentioned fossil occurs are referred by Mr. C. L. Griesbach[2] to the upper part of the lower trias (upper Muschelkalk). Crinoids and corals are not uncommon in the Sonámarg rocks, and one of the latter has been provisionally assigned to the genus *Cyathophyllum*.

Between Báltal and the Zoji-lá the limestones of the supra-Kuling series are succeeded by shaly and calcareous rocks, frequently carbonaceous, and crowded with crystals of pyrite, which seem to represent the Kuling series south of Sonámarg.[3] Nearer the pass the Kuling rocks are in turn overlain by slates, and greenish trappoid rocks, which on the Drás side frequently become converted almost into mica-schist. There is little doubt but that these rocks are the representatives of the older palæozoic, or Panjál system, and that they form a concealed anticlinal axis; the succeeding rocks to the southward being inverted, while those to the northward are in normal sequence, as is displayed in the accompanying figured section (plate III., figure 4). In the neighbourhood of the pass itself the rocks are much bent and contorted, and immediately on the northern side there occurs an infolded band of limestone, some fifty feet in thick-

1 "Memoirs," Vol. V., p. 349.

2 "Records," Vol. XIII., p. 103.

3 This is the view entertained by Dr. Stoliczka. See "Scientific Results of Second Yarkand Mission.—Geology," p. 12.

ness, probably representing some part of the Zánskár system. Alternations of slates, semi-schistose rocks, micaceous sandstones, and quartzites, with a general north-easterly dip, continue till within about half-a-mile of the village of Matayan (Mataian), where they are followed by carbonaceous shales and earthy limestones, which seem to be the representatives of the Kuling series. These rocks are in turn overlain by the typical thin-bedded limestones, dolomites, and shales of the supra-Kuling series. The calcareous rocks are sometimes pure white and dolomitic, when they are usually more massive; while they are at other times earthy and black. In his first notice of these rocks,[1] Dr. Stoliczka mentioned a shell which he considered "scarcely different from *Megalodon columbella*, *Hörnes*, from the upper triassic Alpine limestone," as being very common in these rocks; and considered that some of the latter were probably the same as the Pára limestone of Spiti. In his later notes,[2] however, the only shells mentioned are "*Rhynchonellæ*, and sections of large bivalves, like *Megalodon* and *Dicerocardium*, and small oysters; but nothing sufficiently determinable." It is, therefore, safer merely to refer these rocks to the supra-Kuling series without further approximation to their precise geological age.

At Matayan there is a small fold in the white dolomitic limestone, and below this the same rocks continue, with a southerly or south-westerly dip, as far as the great bend of the Gumbar river. At this point the supra-Kuling rocks are in contact with trappoid and slaty rocks of the Panjál system, with a north-easterly dip, and it is, therefore, presumed that the junction is a faulted one. To the eastward of this point the dolomitic rocks of the supra-Kuling

1 "Memoirs," Vol. V., p. 349.
2 "Scientific Results of Second Yarkand Mission.—Geology," p. 12.

series continue along the southern side of the Drás valley, forming the magnificent and lofty castellated cliffs which are such a striking feature in the scenery of this valley.

Immediately to the south of Drás itself small outlying patches of the supra-Kuling rocks may be observed resting here and there upon the palæozoic trappean rocks, and it has, therefore, been concluded, irrespective of the question whether the whole of the line of junction between the supra-Kuling and the Panjál rocks is a faulted one, that wherever in this district the rocks of the Zánskár and Panjál systems are in normal succession the Kuling series has been included in the trappean rocks, and cannot consequently be recognized as a distinct formation, To the southward of Drás the easterly limits of the Zánskár rocks are defined by a line running in a direction nearly north and south, at a distance of about eight miles to the westward of the Suru river, aud continuing to the south-eastern extremity of the Zánskár area at the Bhot-kol pass. Along this line the limestones and dolomites of the supra-Kuling series, which are here more massive and thick-bedded than in the Sonámarg neighbourhood, are conformably underlain by carbonaceous, and pyritiferous, crumbly shales, alternating with thin-bedded blue limestones traversed by veinings of yellow quartz. From their relative position and petrological composition there is little doubt but that these rocks correspond to the Kuling series of the Káshmír valley. An outlier of Zánskár rocks, too small to be marked on the accompanying map, occurs due west of Kartse, distant about half way between that place and the eastern boundary of the main area of Zánskár rocks; it rests conformably upon metamorphic rocks, and will be further alluded to in the sequel.

In the neighbourhood of the Bhot-kol pass it will be seen from

the map that the south-eastern angle of the great area of Zánskár rocks terminates in an irregular manner among the metamorphic rocks of the north-western extremity of the Zánskár range. The best idea of the relations of the different rock-systems in this neighbourhood will be gathered by a description of the section from Suru across the Bhot-kol pass into the Wardwan valley. Proceeding from Suru up the narrow ravine leading to the pass, an ascending series of imperfectly crystalline schists, among which there occur a few beds of white granitoid gneiss, is met with. At the point where the stream divides into its two component branches there occurs a synclinal of the limestones and dolomites of the supra-Kuling series, resting conformably on the sub-metamorphic schists, but with frequent inversion on one or the other side. Bands of shale, weathering to a chestnut-brown colour, alternate with the limestones and dolomites; and the latter are here and there altered to a completely crystalline marble. From the relation of these calcareous rocks to the subjacent metamorphics, it is evident that in this district the whole of the rocks below the supra-Kuling series have been affected by metamorphic action; and consequently that the Kuling series must be represented among the higher schists, although it cannot be distinguished as a distinct formation. Nearer the pass the metamorphism of the rocks underlying the supra-Kuling series gradually becomes less and less marked, and traces of the carbonaceous shales and quartz-veined blue limestones of the Kuling series can here and there be detected, and are approximately represented on the map. The summit of the pass consists of the supra-Kuling limestones and dolomites; but on either side there occurs a massive and light-coloured granitoid gneiss, occasionally overlain by what appear to be the representatives both of the Kuling and the supra-Kuling series: on the western side of the pass this gneiss is overlain by decidedly supra-Kuling rocks, with

a low westerly dip. Between the pass and Rangmarg,[1] in the upper Wardwan valley, there occurs on the right bank of the river another mass of the same granitoid gneiss, overlain to the south and west by dark slates and the characteristic supra-Kuling rocks. These slates contain bands of a greenish serpentinous rock, identical with a similar rock underlying the supra-Kuling series of Shigar (described below), and it is accordingly presumed that these rocks are the partially altered Kuling series. The determination of the rocks below the supra-Kuling series is however, in this district an extremely difficult matter, owing to the complex relations of the different systems and the metamorphism to which they have been subjected: all determinations must, therefore, be considered as more or less provisional.

The rocks of the upper part of the Wardwan valley consist of the limestones, dolomites, and shales of the supra-Kuling series, frequently crowded with crinoid-stems, corals, and comminuted shells. To the northward of the main valley, in the tributary Kudarun (Kardaran) valley, the supra-Kuling rocks are apparently overlain by the Kuling and older palæozoic rocks of the Zoji-lá, which seem to occupy an inverted anticlinal axis. The rocks to the southward of the supra-Kuling series are well exhibited in that portion of the Wardwan valley immediately below the first great bend of the river. The rocks of the supra-Kuling series above that bend are underlain by a thin bed of carbonaceous and calcareous shales with numerous crystals of pyrite, and rusty spots, probably representing decomposed fossils. This shaly bed, which is only about one hundred feet in thickness, is in turn underlain by a great mass of trappoid, and generally amygdaloidal, rocks, without any distinct stratification: beneath these trappoid rocks there again occur carbonaceous shales,

1 Not marked on the accompanying map.

dark shaly and fissile limestones, and pale quartzitic sandstones, all with a low north-easterly dip. In these rocks there are great numbers of the brachiopods and polyzoans characteristic of the Kuling series of the Káshmír valley, together with crystals of pyrite. As in the latter area, the brachiopods are more abundant in the calcareous, and the polyzoans in the argillaceous rocks. Beneath the Kuling series come the sedimentary rocks of the Panjál system which extend far down the valley.

In the foregoing section, which is diagrammatically represented in figure 3 of plate III., it would seem from their similarity in petrological composition, and from their relative position, that the shales underlying the supra-Kuling series are the same as the undoubted Kuling rocks to the south of the trappean band; and consequently that the latter really forms an anticlinal axis below the Kuling rocks, the original relations of the rocks having been rendered obscure by flexure and inversion. The Kuling rocks to the north of the trappean band are somewhat thinner than those to the south; a relation which may probably be explained by their lower beds being more mingled with the trap on the one side than on the other. The whole section is, indeed, precisely analogous to the one already described in the Sind valley, and also to the one in the upper Lidar valley, the different bands of rocks being apparently in connection throughout this extent of country.

The foregoing sections are in reality amply sufficient to explain the relations of the Zánskár rocks in this district, but since a section in the upper Lidar valley has been the cause of much confusion in regard to the age of the slates of the Zoji-lá, it may be well that it should be noticed here. It must be premised that many of the names mentioned in this section are not to be found on the accom-

panying map, though given on the larger-scaled maps of the Indian atlas. Leaving the first band of the Kuling series met with after passing the Zánskár rocks of Pailgám, the trappean Panjáls continue as far as the herdsmen's camping-ground of Chandanwari, where they are again overlain by the rocks of the Zánskár system, in which the Kuling series forms an ill-defined zone at the base. Between the latter place and Amrnáth cave, on the road leading by the Koun-Nág, the darker limestones low down in the series are interstratified with thick beds of slate and sandstone, and continue up to Astonmarg, where bands of dolomitic limestone become common; they are succeeded by pure white dolomites continuing as far as the Koun-Nág. At this point the dolomites are overlain by blue limestones, sandstones, carbonaceous shales, and slates, while still further in, to the westward of Panjtárni trigonometrical station, the strata consist entirely of dark slates, schists, and sandstones, with the same north-easterly dip, and with much contortion. Still further north, to the south of Panjtárni camping-ground, the characteristic strata of the Zánskár system are again met with, having a pretty constant south-westerly dip and apparently underlying the slaty rocks, which are continuous with the slates of the Zoji-lá. From the evidence of this section it was formerly considered that the Zoji-lá and Panjtárni slates were newer than the trias, a view which has been shown not to be the true one. The latter section must probably be explained by considering that the rocks of the Panjál system form a concealed anticlinal below the Zánskár rocks, and spread out on the surface in a fan-like manner so as to simulate the appearance of occupying a synclinal axis in the latter.

The rocks of that part of the area under consideration lying to the westward of Drás may now be noticed, which is best done by

following the road from that place across the high pass leading into the Tilel district of the Kishanganga valley. Leaving Drás, and following the course of the Mushki stream, the Zánskár rocks are continued for some distance to the south of the main road; approaching the pass, however, the slates and shales of the Panjál system are gradually succeeded by carbonaceous shales, and thin blue limestones with quartz veinings, till at the pass itself blue limestones constitute the greater part of the rocks: these blue limestones are overlain by massive dolomitic rocks like those to the south of Drás. It is difficult, in the absence of any fossils, to separate the Kuling from the supra-Kuling series in this district, and the boundaries on the map must consequently only be regarded as approximate: the fault which has been supposed to exist in the neighbourhood of Drás has here completely died out, the rocks of the Zánskár and Panjál systems being in perfect conformity. On the right bank of the Kishanganga, in Tilel, there is an anticlinal axis in the Panjál system, and to the north of this a synclinal, in which there occurs a broken line of outliers of the lower Zánskár rocks. The Zánskár rocks occupy the whole of the centre of the Kishanganga valley till some eight miles below Gurez, as is shown on the map; the more massive dolomitic rocks overlying the thinner-bedded limestones. An extension of the lower part of the system runs some distance up the valley of the Burzil stream,—on the Gurez and Gilgit road—the strike of the beds having acquired a local north-east and south-west direction. The presumed representatives of the Kuling series consist of carbonaceous shales, and thin-bedded blue limestones with quartz veinings, and appear to be more developed on this side than on the southern border of the area of Zánskár rocks. On the Burzil river the Kuling series occupies the summits of the ridges and spurs on the right bank of the stream, and forms the greater part of the

precipitous cliffs on the opposite side, the dip being nearly due east. In places these rocks are remarkable for the extraordinary amount of contortion to which they have been subjected; and the Panjál rocks near the Dorikun pass are inverted on the Kuling series. To the north-west of Gurez the strike of the Zánskár rocks sweeps round to become continuous with that in the neighbourhood of the Burzil stream, the rocks of this system being regularly underlain by the Panjál rocks.

The woodcut forming the frontispiece (plate I.) to the present memoir, from a larger monochrome painting by Colonel Tanner, shows the great mass of Zánskár rocks in the Gurez valley. The sketch is taken from close to Gurez fort, the tributary valley on the left being the mouth of the Burzil stream, and the valley on the right the continuation of the Kishanganga valley into Tilel. The snow mountains in the extreme left form the gneissic range of the Dorikun pass. The dark hill on the right of the picture consists of the Panjál rocks, overlain by the lower Zánskár rocks, which are seen dipping to the left (north-east). The great triangular mountain in the centre of the picture, which forms such a striking feature in the Gurez valley, is composed of the massive dolomitic supra-Kuling rocks, and the absence of distinct stratification in these rocks is well exhibited in the picture. The sloping hill on the left of the picture, in front of the Burzil valley, also consists of the same rocks, which have a north-easterly dip, and further to the left are probably inverted under the Kuling rocks. In this ridge the rocks in many places exhibit numerous sections of a large species of *Megalodon*, which may be either *M. triqueter* (Wulf), of the Pára limestone of Spiti, or *M. gryphoides* (Gümbel), of the upper trias (keuper) of the Alps. At the mouth of the Burzil stream a large discoidal cepha-

lopodous shell (possibly a *Ceratites*) was observed by the present writer in 1874, on the face of a huge slab of the dolomitic limestone, but was too bulky for removal.

The notice of these rocks may be concluded by the description of an oblique section taken through them from the village of Badagám in Tilel, to Sonámarg in the Sind valley. In crossing the steep ridge on the left bank of the Kishanganga opposite Badagám, dividing it from the narrow gorge known as the Láhan valley, there is first an ascending series of light blue limestones, with a southerly dip, followed by bands of white dolomitic limestones, blue limestones, green slates, and a peculiar white slaty limestone. On the Láhan stream itself, there occurs a thick band of brown slates; and similar rocks intermingled with a few bands of limestone, with the same southerly dip, extend half-way up the ridge dividing the Láhan and Gadasír streams; these are succeeded by a great thickness of limestones and dolomites. The last mentioned ridge forms a synclinal axis, and the same beds are met with on the opposite side in the reverse order: the slates seen on the Láhan stream are not, however, exposed. As these supra-Kuling rocks have not the homogeneous character which they present in the Gurez valley, they do not weather out into craggy and castellated cliffs like those of Gurez and Drás, but into parallel ridges and hollows, resembling the corresponding rocks of Sonámarg and the Káshmír valley. On the left bank of the Gadasír stream the amygdaloidal rocks of the Panjál system come in below the Zánskár series, and the section is then the same as the one described in the Sind valley. Numerous springs, supplying the two small lakes called Vishan-Sár, occur on the line of junction of these two rocks, and it was formerly considered they indicated that the junction was a faulted one: the impervious nature

of the amygdaloidal rocks may, however, account for their presence without the aid of a fault. At the head of the Gadasír stream the weathered surfaces of the calcareous rocks are covered with numerous corals, some of which have been considered to belong not improbably to the genus *Chætetes*, elsewhere known from the silurian and carboniferous.

The foregoing sections seem to indicate that there is a very considerable amount of local variation in the petrological composition of the rocks forming the supra-Kuling series, which, in the general absence of organic remains, will greatly increase the difficulty of the future geologist who undertakes the serious task of dividing this series in the Káshmír basin into minor groups, corresponding with those of Spiti.

Outliers in the northern division of the Káshmír basin.

In the basin of the Kishanganga, below Gurez, and to the north of the long axis of the Káshmír valley, there occur several small outliers of Zánskár rocks. One of these, apparently containing representatives both of the Kuling and the supra-Kuling series, and occupying a synclinal in the Panjál slates, is situated high up on the southern barrier of the Kishanganga valley, due north of the Loláb district of Káshmír. In the bottom of the Kishanganga valley at the village of Changa, and again between that place and Shárdi, there occur overlying the metamorphic schists, or sometimes folded in among them, certain more or less altered limestones and dolomites, which seem in all probability to be the representatives of the supra-Kuling series. Owing, however, to the effects of metamorphic action, the representatives of the Kuling series cannot be distinguished from the underlying rocks.

Above Shárdi, in the tributary valley to the north of the Kishanganga, between the Kankatori and the Fulmai streams, which, though not named on any of the maps, is known as the Brai valley, there occur at the upper end numerous small outliers of the characteristic calcareous and dolomitic supra-Kuling rocks, more or less altered by metamorphism. These rocks conformably overlie the schists, and are sometimes found capping the highest peaks and ridges, and at others let deep down into the river gorges, being not unfrequently completely inverted among the gneiss. As in the last case, metamorphic action has obliterated all the characteristic features of the Kuling series beyond the possibility of recognition The position of these outliers is such that they lie exactly on the line of the strike of the Zánskár rocks of Gurez and Tilel, indicating the original extension of those rocks over the intermediate area. It may be mentioned in connection with these rocks that the early Himalayan traveller, Mr. G. T. Vigne, in his sketch map illustrative of the geology of Káshmír,[1] has indicated the occurrence of dolomitic limestones in the valley of the Indus in the now inaccessible country of Chilás, directly on the line of the Zánskár rocks of Gurez, and the above-mentioned outliers of the same. It is probable that the limestones of Chilás indicate a still further extension of the former rocks.

Fossils of the Káshmír basin.

In the following list there are recorded all the determinable fossils hitherto obtained from the Zánskár rocks of the two divisions of the Káshmír basin. The determination of the brachiopods rests chiefly upon the memoir of Mr. T. Davidson, quoted in the introductory chapter. Most of the gastropodous genera are given on the

1 *Op. cit.*, Vol. I., p. 275

authority of Dr. Verchère; while the other forms have been chiefly determined by Dr. Feistmantel, on the evidence of specimens collected by Colonel Godwin Austen and the present writer.

I.—SUPRA-KULING SERIES.

Cephalopoda	1.	Ammonites (Ptychites) gerardi. Blanford. Senámarg.
	2.	(?) Ceratites sp.—Gurez.
	3.	(?) Goniatites sp.—Víhi.
	4.	Orthoceras sp.—Mánas-Bal.
Gastropoda	5.	(?) Chemnitzia sp.—Víhi.
	6.	(?) Loxonema sp. ,,
	7.	(?) Macrochilus sp. ,,
	8.	(?) Naticopsis sp. ,,
	9.	(?) Nerinæa sp. ,,
Lamellibranchiata	10.	Megalodon (?) gryphoides, Gümb.—Gurez and Víhi.
	11.	(?) Aviculopecten sp.—Víhi.
	12.	(?) Axinus, sp. ,,
	13.	(?) Cardinia or Anthracosia sp.—Víhi.
	14.	(?) Solenopsis sp.—Víhi.
Brachiopoda	15.	Spirifer (?) stracheyi, Salt.—Víhi.
Crinoidea	16.	Gen. non. det.—*Passim*.
Anthozoa	17.	(?) Cyathophyllum sp.—Sonámarg.
	18.	(?) Chætetes sp.—Gadasír.

II.—KULING SERIES (all from the Káshmír valley).

Cephalopoda	19.	Orthoceras sp.
Lamellibranchiata	20.	Avicula, sp.
	21.	Aviculopecten, sp.
	22.	Solenopsis, sp.
Brachiopoda	23.	Athyris subtilita. Hall.
	24.	,, royssi. L'Ev.
	25.	Camerophoria sp.
	26.	Chonetes (?) austenia. Dav.
	27.	,, hardrensis, Phil., v. tibetensis.[1] Dav.
	28.	,, lævis. Dav.
	29.	Discina kashmiriensis. Dav.
	30.	Orthis, sp.
	31.	Productus cora. D'Orb.
	32.	,, costatus. Sow.

1 This name was given on the supposition that the fossil came from Tibet: it should be changed to *kashmiriensis*.

Brachiopoda	33.	Productus humboldti. D'Orb.
	34.	,, lævis. Dav.
	35.	,, longispinus. Sow.
	36.	,, scabriculus. Mart.
	37.	,, semireticulatus. Mart.
	38.	,, (?) spinulosus. Sow.
	39.	,, striatus. Fisch.
	40.	Retzia, sp.
	41.	Rhynchonella barusiensis.[1] Dav.
	42.	,, kashmiriensis. Dav.
	43.	,, pleurodon, v. davreuxiana. D. Kon.
	44.	Spirifer barusiensis. Dav.
	45.	,, kashmiriensis. Dav.
	46.	,, keilhavi, Buch. (S. raja. Salt).
	47.	,, moosakhailensis. Dav.
	48.	,, striatus. Mart.
	49.	,, vercheri. Vern.
	50.	,, vihiana. Dav.
	51.	Spiriferina octoplicata. Sow.
	52.	Streptorhynchus (Orthis) crenistria. Phil.
	53.	Strophomena rhomboidalis, Wehl., v. analoga. Phil.
Polyzoa	54.	Terebratula austeniana. Dav.
	55.	,, sacculus. Mart.
	56.	Fenestella (?) lepida. D. Kon.
	57.	,, sykesi. D. Kon.
	58.	,, megastoma. D. Kon.
	59.	Protoretepora ampla. Lons.
	60.	Vincularia multangularis. Port.
Trilobita	61.	Phillipsia (?) semenifera, (Phil.)

Of the foregoing fossils, No. 1 is figured by Mr. H. F. Blanford;[2] No. 10 may very probably be the same as the species figured in plate IV. of this memoir; Nos. 27,[3] 37, 43, and 54 are figured on plate I. of volume XXII. of the "Quarterly Journal of the Geological Society," where they are erroneously stated to have been obtained from Shigar, in Baltistán, in place of from the Káshmír valley. Nos. 23, 26, 28, 29, 33, 34, 36, 37, 38, 41, 42, 44, 45, 46,

1 Misnamed *berumensis* in Mr. Davidson's memoir: it should be named from the village of Barus in Víhi.

2 "Jour. As. Soc. Bengal," 1863, plate II., fig. 6.

3 This species was first mentioned under the name of *Productus hardrensis*, but subsequently as *Chonetes*.

47, 50, 52, and 55, are figured in plate II. of the same volume of the "Quarterly Journal." Nos. 56, 57, and 58, are figured in plate I. of volume XIX. of the same publication. In plate II. of the present memoir the following five fossils are figured—*viz.*, Nos. 33, 37, 48, 59, and 61: the latter (*Phillipsia* (?) *semenifera*) may be compared with the figure of *Asaphus* (*Phillipsia*) *semeniferus* given by Professor Phillips.[1]

No precise deductions as to the age of the rocks in which they occur can be drawn from the evidence of the specifically undetermined forms. With regard to the named species, Nos. 1 and 15 occur in the Liláng group of Spiti, while No. 10 is probably the same as an upper triassic Alpine species. It may, therefore, be safely affirmed, as already said, that the supra-Kuling rocks of the Káshmír basin correspond at all events in part to the trias; it is, however, quite probable that they may extend up into the jura. Numbers 35, 37, 46, 47, occur in the Kuling series of Spiti, and it is on the evidence of these four species, coupled with the corresponding serial position of the two horizons, that the carboniferous rocks of Káshmír are correlated with the Kuling series of Spiti. In many instances, as in the case of *Productus semireticulatus*, the fossils from Káshmír and Spiti are absolutely indistinguishable from one another, and if mixed together it would be quite impossible to assign their respective places of origin to particular specimens. This resemblance, coupled with the fact that these four fossils occur in both areas solely in one particular horizon, and never range up into the higher beds, which are also fossiliferous, ought to leave no doubt that the Kuling series of Spiti corresponds precisely with the beds which have received the same designation in Káshmír.

1 "Geology of Yorkshire," 1836, plate XXII., fig. 10.

Comparing the fossils of the Káshmír Kuling series with those of the carboniferous of other regions it will be found that of the species in the preceding list the following are common to the mountain limestone, or lower carboniferous, of Europe, *viz.*, Nos. 23, 24, 27, 31, 32, 33, 35, 36, 37, 38, 39, 43, 51, 52, 53, 60, 61[1]: or a total of no less than seventeen species. The following species are common to the Kuling series of Káshmír and the carboniferous of Australia, *viz.*, Nos. 24, 27, 31, 35, 36, 37, 47, 48, 51, 52, 53, 59; or a total of twelve species. In the carboniferous, or "Productus-limestone,"[2] of the Salt-range in the Punjab the following species of the Káshmír Kuling occur:—*viz.*, Nos. 23 (var.), 24, 31, 32, 33, 35, 37, 39, 43 (var.), 47, 48, 51, 52, 56, 57, 58; or sixteen species. These comparisons prove conclusively that the Kuling series must be regarded as the homotaxial equivalent of the lower carboniferous of Europe and Australia, and must also be the same as the "Productus-limestone" of the Punjab. It might, perhaps, be considered from the foregoing comparisons that the affinity of the Kuling series of Káshmír to that of Spiti is less marked than its affinity to the carboniferous of the more distant regions with which its fauna is compared. When, however, it is remembered that only seven species of fossils,—all brachiopods—have been determined from the Kuling series of Spiti,[3] and that out of these seven four are identical with Káshmír species the apparent discrepancy at once vanishes.

With regard to the homotaxial equivalency of that part of the supra-Kuling series, immediately overlying the Kuling series, there is

1 The last, if not absolutely the same, is exceedingly close to the European species.

2 "Manual," pt. II., p. 492. The brachiopods (and other fossils) of the Productus-limestone are now in course of description by Dr. Waagen in the "Palæontologia Indica," and there may be additions to this list. The homotaxial equivalency of the series will be discussed by Dr. Waagen at the conclusion of his work.

3 "Memoirs," vol. V., pp. 27-29.

a considerable amount of difficulty in arriving at any satisfactory conclusion, and, as already said, with the materials at hand it seems better not to press the question too closely. The ammonite from Thájwáz (*Ammonites (Ptychites) gerardi*) is referred by Dr. Stoliczka to the upper trias (keuper), but, as already said, Mr. Griesbach[1] would rather consider it characteristic of the upper part of the lower trias (Muschelkalk). The safer plan for the present is, therefore, to be content with saying that in the Káshmír basin strata having a fauna agreeing with that of the lower carboniferous of India, Australia, and Europe, are conformably succeeded by strata of which the fauna, as far as known, has a triassic facies. It may be added that the existence of *Goniatites* in the supra-Kuling series of Káshmír rests apparently on a determination made in the field by Colonel Godwin Austen, who considered that all these strata were of carboniferous age. Although the genus does occur in the trias of Europe, it attained by far its greatest development in the carboniferous, and it may accordingly be not impossible that the Káshmír cephalopod has been incorrectly determined.

1 "Records," vol. XIII., p. 103.

Chapter VII.—THE ZÁNSKÁR SYSTEM, OR MESOZOIC AND CARBONIFEROUS ROCKS (Continued).

The Zánskár basin; the Chamba basin; the Chángchenmo and Kárákoram basin; the Baltistán basin; the basin of the Outer Hills; the Khágán valley; former union of areas of Zánskár rocks.

The Zánskár basin. The next area in which the Zánskár rocks may be considered is that part of the Zánskár-Spiti basin lying within Káshmír territory, which, as above noticed, may conveniently be simply termed the Zánskár basin. In the accompanying map somewhat more of the south-eastern extremity of this basin is geologically coloured than belongs to Káshmír territory, the boundary of the coloured area being carried as far as the southern limits of the water-basins of the Tsárap and upper Pára rivers, which in some of the older maps is given as the boundary of Káshmír territory. The dotted line (—.—.—.) on the accompanying map running to the north-east of the Tsárap valley, and crossing it higher up at Sarchu is the modern boundary of Káshmír territory, and the geological descriptions given below will not include the country to the south of that boundary. The southern portion of the Zánskár rocks coloured in the map, below the Káshmír boundary, comprehends a part of the district in which the typical Zánskár (mesozoic, etc.,) rocks were originally described by Dr. Stoliczka, and for their description the reader is accordingly referred

to his original memoir.[1] It may be mentioned in passing that the Pára river occurring in the area geologically coloured, but not described in this memoir, gives the name to the Pára limestone, while the pass at the head of its valley (Takling of the map) gives the name to the Tágling group.

The Zánskár rocks of the north-western extremity of the Zánskár basin are, as will be seen from the map, separated only by a narrow strip of older palæozoic (Panjál) rocks from the Zánskár rocks of the northern division of the Káshmír basin at Drás, and it will be convenient to commence their description at that end. In the neighbourhood of Shargol it is found that the strata to the south of the narrow zone of sedimentary tertiary rocks marked on the map have a low southerly dip, and consist of metamorphic and frequently highly carbonaceous shales, generally extremely difficult to distinguish from the tertiary beds. These shales are conformably overlain by a great thickness of limestones and dolomites, similar to those of Drás, which form the whole of the higher hills to the southward of Shargol. Among these calcareous rocks, in the ravine opposite the last-named place, there occur in a blue limestone at some little distance above the base great numbers of a large species of *Megalodon*. This shell, of which there is a fine specimen in the Indian Museum, represented in plate IV., seems to differ from *Megalodon triqueter*,[2] Wulf, of the Pára limestone of Spiti, and of the Dachstein limestone (rhætic) of the Alps, by the larger size of the umbones and the deeper groove at the hinge, and seems to be indistinguishable from *M. gryphoides*,[3] Gümbel, of the upper trias

1 "Memoirs," vol. V., pt. I.

2 *Ibid*, p. 64. "Manual," pt. II., figs. 8, 8a.

3 'Sitz. d. k. Akad. Wien,' vol. XLV., p. 372 (figure).

(keuper) of the Alps. The Shargol limestone may, therefore, be referred to some part of the trias; and not improbably, as being at the base of the calcareous series, corresponds to the Liláng group.[1] The underlying shales, which generally weather to a peculiar light-brown colour, may without much doubt be referred to the Kuling series, although in the absence of fossils the upper boundary of this series can only be approximately given. To the eastward of Shargol the representatives of the same shales are still difficult to distinguish from the tertiaries, and contain what appear to be interstratified lenticular masses of blue quartz-veined limestone, although it is possible that these may be outliers of the supra-Kuling rocks.[2] Farther to the east of Shargol the presumed Kuling shales are continued along the line of the Káshmír and Ladákh road; while to the north of Kharbu a few small outliers of supra-Kuling slates and limestones are found resting on them, and they become a good deal mixed up with the tertiary trap, which has partially altered them. At Lámayúru and in the ridge to the north of Kharbu, the Kuling rocks are conformably underlain by variously coloured slaty rocks among which Dr. Stoliczka[3] recognized the greenish trappoid Panjál rocks of Drás, and in the Lámayúru gorge the representatives of his Múth and Bhábeh series. The latter observations, which will be further alluded to in a subsequent chapter, remove any elements of

1 It is unnecessary to go into the question whether the trias of Shargol has any representatives of the lower trias between the *Megalodon* beds, and the Kuling series, since there is no evidence to decide the point.

2 Dr. Stoliczka ("Scientific Results of Second Yarkand Mission.—Geology," p. 13), after mentioning the difficulty of distinguishing the carboniferous and tertiary shales, when referring to the above-mentioned Kuling shales east of Shargol, observes that "there are lumps and patches of it [trias limestone] very often sticking out of the *so-called* tertiary shales," showing that he doubted their tertiary age.

3 *loc. cit.*

doubt which may be remaining as to the identity of the Shargol shales with the Kuling series.

From the Fotu-la and Lámayúru the Kuling zone extends in a south-easterly direction, its northern boundary running through the village of Wánla, across the Chokelah pass to the Zánskár river, beyond which it is continuous for some distance with the southern boundary of the sedimentary tertiaries: the dip of these rocks is in general to the south-west. Near Skiu (Kio) the lowest exposed beds are placed nearly vertically, and consist of blue-black limestones, traversed by veins of yellow quartz, and overlain by the characteristic brown and black shales with quartzitic bands: many of these shales are highly carbonaceous, and crowded with small crystals of pyrite; thus closely resembling the Kuling series of the Káshmír valley: crinoid-stems and corals are also of common occurrence in these limestones. In speaking of these rocks at Skiu, Dr. Stoliczka observes:—"The nummulitic rocks are suddenly replaced by slates and carbonaceous limestones full of crinoid stones, which appear to be of carboniferous age. All the way up from Keu (Skiu) to the head of the Markha valley, nothing but these carbonaceous crumbly slates occur;" and it is concluded that they contain representatives both of the silurian and carboniferous rocks. Such, indeed, may very possibly be the case, but the presumption is that they correspond in the main to the Kuling series, although, as already stated, the boundaries of the different rock-series in this region given on the map must only be considered as approximate.. On the Markha river a short distance below Skiu the yellow quartz in the slaty shales is in great force. In the upper part of the basin of the same river, the band of Kuling rocks splits and encloses the wedge-shaped north-western extremity of the Panjál and metamorphic rocks

of Rupshu. The northern branch of the Kuling rocks seems to disappear some twenty miles to the south-east of the Gya river, between the Rupshu metamorphics and the Indus tertiaries. On the upper Gya river the Kuling rocks have undergone great crushing and contortions: they consist a little south of Gya itself of shales weathering to a brown tint, interstratified with blue quartzitic limestones, often occurring in lenticular masses: the shales are frequently quartzitic and carbonaceous, and dip towards the tertiaries, which they closely resemble. To the southward of Gya there is at first a folded series of the Kuling rocks, underlain to the south by blue slates and micaceous sandstones of the Panjál system. Near the Taglung pass there occurs a synclinal depression in the latter rocks, containing what are apparently representatives both of the Kuling and the supra-Kuling series. The former consists of the usual shales, quartz, and limestones; and there occur near the pass itself large lenticular masses of pure white saccharoid quartzite. The supra-Kuling series consists of the usual dolomitic limestones mixed with some reddish shales.

To the south-west of the Panjál and metamorphic rocks of Rupshu, the Kuling rocks are again met with conformably overlying the former: this band is continuous with the southern band of the splitting on the Markha river; and to the south-east is continued to the southward of Tso-Moriri into Spiti. In this neighbourhood, at the opening of the Pangpo stream into the Phirsa (Phirse) valley, rocks of the supra-Kuling series with characteristic Liláng fossils were observed by Dr. Stoliczka[1] overlying the shales and slates which "can only belong to the Kuling series, being perfectly identical with the rocks of this [series] in mineralogical characters and geological

1 "Memoirs," Vol. V., p. 343.

position, underlying the Liláng limestones." At Kyangchu, on the Ladákh and Kulu road, the Kuling rocks consist of the pyritiferous shales of Skiu, with similar lenticular quartzitic limestones, succeeded by banded limestones alternating with highly carbonaceous shales, which continue in a V-shaped hollow some distance up the valley leading to the Láchálung pass.

Having now described the north-eastern boundary of the Zánskár rocks in the Zánskár basin, it may be observed that most of the rocks south of the Kuling band consist of supra-Kuling rocks, and it will be most convenient to relate the little that is known regarding this vast development of rocks, by describing several traverses that have been made across the area by Dr. Stoliczka and the present writer. The first of these traverses is one made by the former geologist from Skiu to Padam, the chief place in the Zánskár valley.[1] It is stated that in crossing the ridge to the south of Skiu (Zalungkarpo pass), separating the Markha and Kharnak (Karnag) valleys, the rocks consist of limestones from which were obtained specimens of *Ammonites ausseanus*,[2] Hauer, and *Monotis salinaria*,[3] Bronn, the former a characteristic fossil of the Liláng series of Spiti, and both shells occurring in the trias of the Alps, the second being characteristic of the Hallstadt beds.[4] Here, therefore, beds with a clearly upper triassic *facies* are found not far above the Kuling series, as is apparently the case at Shargol. These Liláng rocks, which are estimated at 1,000 feet in thickness, are succeeded by limestones of the Pára group, with a thickness of about 500 feet,

1 "Memoirs," Vol. V., p. 344, *et seq.*

2 *Ibid*, p. 63.

3 "Manual," pt. II., plate II., fig. 6.

4 See Lyell's "Elements," 6th Edition, p. 433. Geikie, "Text Book of Geology," p. 769, and "Records," Vol. XIII., p. 98.

Dolomitic limestones, which are compared to the "hauptdolomit" of the Alps, and apparently considered to be the same as the Pára limestone, form all the higher ridges between the Kharnak river and the Skapodak (Shapodog) pass, being underlain in the lower valleys and at the junctions of lateral streams by the Liláng limestone, and certain slaty rocks probably belonging to the same group. The Pára limestone is contorted and disturbed to a great extent, and is full of specimens of *Dicerocardium himalayense*, Stoliczka,[1] of the corresponding limestone of Spiti, and of *Megalodon triqueter*, Wulf., of the same group, and of the Dachstein limestone of the Alps.[2] At the foot of the Skapodak pass, Dr. Stoliczka observes,[3] that "the Pára limestone is regularly underlain by a concretionary limestone and sandy slates, which certainly can be only triassic, and probably include some of the reddish and greenish slates of lower triassic age." As in the context the strata in the neighbourhood are all referred to the Pára, Liláng, and Kuling divisions, it must be inferred that Dr. Stoliczka eventually came to the conclusion that the Liláng group included representatives of the lower trias: a conclusion which is confirmed by the fact that Mr. Griesbach has described important beds of this epoch in the more easterly Himalaya.[4] It seems, however, from other sections already noticed to be very probable that the lower trias is considerably reduced in thickness in the Zánskár area, and therefore not generally recognizable as a distinct group. It is possible that the beds corresponding to the lower trias may be still further reduced in thickness towards the north-west.

1 "Memoirs," Vol. V., p. 63, plate VII. "Manual," pt. II., plate II., fig. 7.

2 See Lyell, *loc. cit.*, and "Records," Vol. XIII., p. 96.

3 *loc. cit.*, p. 345.

4 "Records," Vol. XIII., p. 94, *et. seq.*

The ridge of the Skapodak pass is described as consisting of the limestones of the Liláng and Pára groups, but they are so involved as to be difficult to distinguish. To the westward of the pass, in the Niri stream, the characteristic lower Tágling limestones, and the Spiti shales were recognized.[1] On the Saiya-Chun (Saiji-lá) pass,[2] leading into the valley of the Zánskár river, lower Tágling limestones, with their characteristic fossils were observed, which continue across the pass, and on the Zánskár side are underlain by the Spiti, Pára, and Liláng groups, the latter consisting of limestones and slates. In the Zánskár valley the rocks consist of highly contorted Liláng límestones, of a light blue colour, overlain here and there on the top of a hill, or on the side of a cliff, where a fragment has been caught up in a contortion, by the much darker Pára limestone, In the neighbourhood of Thonde the rocks of the Liláng group are underlain by dark greenstone-like rocks, and these again by dark slates and sandstones. The former were considered by Dr. Stoliczka to be the representatives of the Kuling series, and they are so coloured in the map: it is, however, quite possible that these rocks may really correspond to the Panjál traps of the Káshmír valley, which have, so to speak, absorbed the Kuling zone: as the present writer has never visited Thonde, it was necessary that the lines on on the map should follow Dr. Stoliczka's data.

The next two sections are taken towards the south-eastern extremity of that part of the area of the Zánskár basin lying within Káshmír territory, one going from the Tsárap valley, in northern Spiti, across the Láchálung pass to Kyangchu, and the other from the same place across the Pankpo pass in the direction of Tso-

1 For the description of the character of these groups see Stoliczka, "Memoirs," Vol. V.

2 To the north-east of Thonde.

Moriri: the former traverse was made by the present writer, and the latter by Dr. Stoliczka. In the Lingti valley, one of the tributaries of the Tsárap valley, the southern side consists of slates, quartzites, and sandstone rocks, doubtlessly representing the Panjál system, and considered by Dr. Stoliczka to belong to the Bhábeh and Múth series, though the sequence is not very clearly exhibited. Most of these rocks are placed nearly horizontally, and the summits of the ridges are capped by shales, blue limestones, and white and purple quartzites. These upper beds probably correspond in part to the Kuling series, as similar rock-specimens in the Indian museum, collected by Dr. Stoliczka from Múth itself, are referred to that series. Here, however, and to the southward in the British district of Láhol, and elsewhere, limestones occur in the upper silurian (Múth) series, and in the absence of fossils it is consequently very difficult to distinguish between the silurian and the carboniferous limestones:[1] the Kuling zone on the map in this district must accordingly be considered as only approximately indicated. On the northern side of the Lingti valley the Liláng limestones, locally capped with the Pára limestones, constitute the prevailing rocks; many of them being highly contorted. The lower part of the Tsárap valley consists of Pára limestone, with local exposures of the Liláng limestone, and of the shales of the Kuling series in the deeper ravines,—each with their characteristic fossils. The upper Tsárap valley, which is in Spiti, and, therefore, not properly within the province of the present memoir, consists mainly of the lower Tágling limestone, in which specimens of *Terebratula gregaria*, Suess, of the Kössen group of the Alps, and *Rhynchonella austriaca*, Suess, of the lias of the same districts, are locally not uncommon. The latter species has been

1 The same difficulty is recorded by Col. Mc'Mahon in Chamba.—("Records," Vol. XVI., p. 38—NOTE.)

obtained by Mr. Griesbach in Húndes from beds referred to the lower lias,[1] which, though occurring above beds which are correlated with the Kössen group, may still possibly be the equivalents of the lower Tágling group of Spiti, The fossils of the latter seem, indeed, as Dr. Stoliczka noticed, to indicate a transition from the uppermost trias (rhætic) to the lower jura (lias), and it is, therefore, impolitic to press too closely the question as to which of these two groups they should be referred.

In the larger maps of the Indian Survey on the northern watershed of the Tsárap valley a spot is marked as Kato station,[2] and it is apparently from this neighbourhood that certain jurassic fossils collected by Colonel Godwin Austen, and described as coming from Kato in Ladákh, were obtained.[3] The fossils are stated to have been obtained from a yellowish limestone, and have been named as follows, *viz.* :—

Brachiopoda	Rhynchonella katonensis. Dav.
	Terebratula tibetensis. Dav.
Lamellibranchiata	Avicula austeniana. Ether.
	,, acuticostata. Ether.
	Pecten katoniensis. Ether.
	,, allied to *P. vagans*.
Gastropoda	Cerithium? like *C. muricatum*.
	Nerinæa, allied to *N. goodhalli*.
	Phasianella tumida. Ether.
	Pleurotomaria moniliformis. Ether.
Cephalopoda	Ammonites, like *A. macrocephalus*.
	Belemnites, like *B. blainvillei*.
	,, ,, ,, *beaumontianus*.
	,, ,, ,, *canaliculatus*.
	,, ,, ,, *hastatus*.

1 "Records," vol. XIII., p. 94.

2 The position of this spot is due north-east of the two small patches o Kuling rocks marked on the accompanying map on the Tsárap river (at the second *a* of the name), on the boundary line (.—.—.—) of Káshmír territory.

3 'Quar. Jour. Geol. Soc,' vol. XX., pp. 387-8, vol. XXII., p. 37. In both these notices Ladákh and Suru are confounded in a most marvellous manner. On page 386 of the former paper the name "Jarrup river" stands for the Tsárap river.

The two brachiopods have been figured,[1] and the second is said to be "not unlike some Cretaceous specimens of *T. biplicata*, and the Jurassic *T. indentata*." The other fossils are apparently only mentioned in the abstract noticed above; and as the species newly named there have never been described or figured, they must consequently be regarded merely as manuscript names. It is said that these fossils present a facies characteristic of the middle jura,—between the Cornbrash and the Oxford clay.

From the fact of these fossils occurring in a limestone, and also from the circumstance that gastropods are of common occurrence among the fossils of the Tágling groups,[2] it is not improbable that the Kato beds belong to the upper Tágling group. Dr. Stoliczka has indeed suggested[3] that the *Nerinæa* mentioned by Mr. Etheridge is the same as one from the typical upper Tágling group, considered to be very close to the European *N. goodhalli*, Fitton, (characteristic of the coral-rag). The upper Tágling group of Spiti likewise contains a fossil very close to *Ammonites macrocephalus*, Schlotheim,[4] (ranging from the great oolite to the Oxford clay).

Mr. Etheridge's conclusion as to the age of the Kato beds would make the upper Tágling group rather higher than is the case according to Dr. Stoliczka, who provisionally correlates it with the middle lias of Europe. It will, however, be recollected that the upper Tágling group is followed by the Spiti shales containing jurassic fossils, some of which, like *Ammonites braikenridgi*, Sow, occur in the lower jura (inferior oolite), while others, like *A. biplex*, are of upper jurassic (Kimmeridge clay) age.

1 'Quar. Jour. Geol. Soc.,' vol. XXII., pl. I. figs. 11-16.

2 See "Memoirs," vol. V., pp. 77, 81-2.

3 *Ibid*, p. 82.

4 Stoliczka, *op. cit.*, p. 83. This species also occurs in the overlying Spiti group.

From the foregoing observations it is probable that the crest of the ridge on the north side of the Tsárap valley consists of the upper Tágling group. Still higher up the valley, in the neighbourhood of the Pangpo pass, the higher ridges consist of the overlying Spiti shales, the crest of the pass itself (18,000 feet) being composed of the lower Tágling limestone. On the very highest crags on either side Dr. Stoliczka noticed patches of a white limestone, from the examination of fallen fragments of which he was led to conclude that it represented the Chikkim (upper cretaceous) limestone of Spiti: this is the most north-westerly point where these rocks have hitherto been detected in the Zánskár-Spiti basin, and, with the probable exception of the Lokzhung mountains, on the extreme north-eastern frontier, the only spot in Káshmír territory where they are known to occur. On the northern side of the Pangpo-lá the lower Tágling limestone forms the prevalent rock. Lower down the valley the underlying Pára, and then the Liláng, limestone comes in, the Tágling group still occurring in force on the ridges. The Liláng limestone continues as far as the mouth of the Pangpo stream, where, as has been shown in an earlier paragraph, it is underlain by the rocks of the Kuling series. It is thus seen that on the south-eastern limit of Káshmír territory the lower jurassic elements of the great Zánskár system occur in considerable force, thus paving the way for the great development of higher jurassic rocks forming the great jurassic ellipse of Spiti, described in Dr. Stoliczka's memoirs.

Reverting to the Lingti valley, and following the road to the north-west across the Láchálung pass, limestones and dolomites constitute the prevalent rocks, till the Kuling zone at Kyangchu is reached. Near the pass itself there occurs an anticlinal axis exposing some shaly beds, which may belong to the Kuling series. In the

neighbourhood of the north side of this pass Colonel Godwin Austen has obtained two species of brachiopods, which are stated to occur abundantly in a compact light grey limestone.[1] These fossils have been described and figured by Mr. T. Davidson,[2] one of them being referred to a new species, under the name of *Waldheimia blanfordi*, and the other to the genus *Rhynchonella* without being specifically determined. The latter is stated to be very close to certain European jurassic species, especially *R. sulcata*. In the notice of these specimens it is observed that they present "a very cretaceous aspect" (although this appears somewhat contradictory to the statement as to the jurassic affinity of the *Rhynchonella*), and from this, and the circumstance that Colonel Godwin Austen believes that he obtained specimens of *Hippurites* from the Indus valley at Khalsi, it is suggested that the Láchálung fossils may have been obtained from cretaceous strata, although it is equally possible that these beds may be of jurassic age. As no traces of the Chikkim (cretaceous) and underlying Spiti series have been detected either by Dr. Stoliczka or the present writer in this neighbourhood, while the lower portions of the Zánskár system are commonly present, it would seem more probable that the fossils are of jurassic age. The character of the rock agrees more nearly with that of the lower Tágling limestone,[3] although the fossils are different from those of that group in Spiti;[4] it is, however, on the whole not impossible that the fossils may belong to some part of the Tágling group. Most of the calcareous rocks on this line probably consist of the lower Tágling, Pára, and Liláng groups, but in the absence of a large series of fossils it is

1 'Quar. Jour. Geol. Soc.,' vol. XXII., p. 38. The locality of the Láchálung (Lacholung) is erroneously given as Suru.

2 *Ibid*, pl. I., figs. 8-10.

3 "Memoirs," vol. V., p. 66.

4 *Ibid*, p. 68, *et seq*.

at present impossible to make any more precise statement regarding them. It is, however, pretty certain that the Pára and Liláng groups are largely developed towards Sumkiel.

The notice of the mesozoic rocks of the Zánskár basin may be concluded by a description of three traverses across the north-western end, made by the present writer. The first of these traverses extends from the south of the village of Wánla to the neighbourhood of Yalchung, on the Zánskár river. Leaving the shaly rocks of the Kuling series near the village of Panjíla (to the south of Wánla), the supra-Kuling rocks consist at first of hard purple and green slates, placed nearly vertically, and alternating with some calcareous bands, and with other beds of pure limestone: these are succeeded by softer and brighter coloured shales, and the latter, at a short distance below the village of Honupatta, by strong blue limestones, with a southerly dip. From that village to the Sarsa pass there is a succession of blue limestones and white dolomites, with a few slates, and some quartzitic beds, which is repeated in a series of folds across the Singhe pass (where Dr. Thompson is stated to have obtained his nummulites[1]) to the Zánskár river. The position of the lower slates in this section would seem to indicate their correspondence with the Liláng group, which has been observed by Dr. Stoliczka to consist locally of similar rocks. The overlying limestones and dolomites are probably the representatives of the Pára, and, perhaps, of the lower Tágling limestones. The slaty character of the lower part of the supra-Kuling series in this district recalls the corresponding rocks of Tilel; while the variability in the petrological characters of these rocks indicates the extreme difficulty of recognizing the separate minor groups of this series in different

1 *Vide supra*, p. 115.

districts, where the aid of organic remains is wanting. The question as to the origin of the above-mentioned nummulites has been already discussed in an earlier chapter.

Near Wánla a large proportion of blue limestone, not unfrequently crowded with crinoids, occurs in the Kuling shales. To the south-east, these rocks consist of hard, black flaggy slates, weathering to the usual light-brown colour, by which character they are distinguished from the older palæozoic slates of Lámayúru, which weather black. At the small village of Urchi, to the south-east of Wánla, a synclinal occurs in the Kuling series, containing the bright-coloured slates and limestones of the supra-Kuling series.

The next section is taken from the village of Hiniskot, near Kharbu, on the Káshmír and Ladákh road, to the gonpa (monastery) on the Sangpo river. At Hiniskot there are lofty cliffs of nearly vertical blue and buff limestones, with a few slaty beds, which from their position would seem to correspond mainly to the Liláng group of Shargol. The same rocks appear to continue till within some two miles of the village of Kangi, where they are overlain by a considerable thickness of coarse sandstones, and these by purple, brown, green and whitish slaty shales, with, at Kangi itself, one bed of crumbly black shales with ferrugino-calcareous concretions. This slate and shale series, which rests apparently at first in a synclinal, and then on an anticlinal, appears to be succeeded to the south by a great thickness of limestones and dolomites. Rocks of the same series continue in several flexures across the Kangi pass to the gonpa on the Sangpo river, in Rundum (Rangdum), where they were observed by Dr. Stoliczka,[1] who considered that several mesozoic

1 "Memoirs," Vol. V., p. 347.

formations were here represented. On this line, following an unpublished map of Dr. Stoliczka, the rocks of the supra-Kuling series are placed in contact with those of the Panjál system, but it is by no means certain that this is correct, and it may be that representatives of the Kuling series intervene. The equivalence of the rocks in the Kangi pass section is by no means clear. The beds on the north, as already said, probably represent the Liláng group, while the dolomites and limestones to the south of the Kangi shales would seem to correspond to the Pára, and (very probably), the lower Tágling groups. It must, however, be observed that the thin bed of crumbly carbonaceous shales at Kangi presents a very remarkable resemblance to the Spiti shale group,[1] but the sequence of the other rocks does not seem to countenance the idea of their being the same; still this may possibly be the case, as there may be concealed faults or inversions.

The third section is taken up the Mulbekh ravine, between the villages of Shargol and Mulbekh. Leaving the Kuling zone on the Wakha stream, there occur limestones, continuous with those of the Liláng group of Shargol, with a southerly dip, which after continuing a distance of about three miles, are succeeded by hard and massive white, green, and purple slates, with occasional sandstones and limestones; the whole series being generally much folded. These rocks are in turn succeeded by the usual dolomites and limestones, which attain a great thickness. The section is the same as the last, with the exception of the absence of the Kangi shales, and, therefore, needs no further notice.

1 "Memoirs," Vol. V., p. 85. The description of the Spiti shale group is as follows:—The rock itself is a black, crumbling shale, breaking into little angular fragments when dry, and easily decomposing to a black soil when wet.. Calcareous concretions occur more or less numerously throughout the series, and contain often, as a nucleus, an ammonite, a belemnite, or some other fossil."

The occurrence of presumed inliers of Kuling rocks within the tertiaries of the Gya valley has been already noticed in a previous chapter. A similar inlier occurs in the bed of the Indus, a few miles below Upshi, at the village of Arpa.

The foregoing description will show how much work remains for the future geologist in connection with the supra-Kuling rocks of the Zánskár basin, and especially with regard to the determination of the different groups at the north-western extremity of the basin. When this difficult task shall have been satisfactorily accomplished, it will afford a foundation for the sub-division of the very similar supra-Kuling rocks of Tilel, while the sub-division of the latter will easily lead on to that of their representatives in the Káshmír valley.

The Chamba basin.

In the Chamba basin, as defined above, a small development of the Zánskár rocks has been described by Colonel Mc'Mahon,[1] but the full extent of these rocks is not yet known. It appears that in the valley of the Rávi these rocks rest in a synclinal of the topmost beds of the underlying Panjál rocks; the bed immediately underlying them being a conglomerate which is considered to be the equivalent of the so-called Blaini conglomerate of the Simla area. The limestone in the neighbourhood of the Rávi is described as being of considerable thickness, and occurring "in massive bands made up for the most part of beds a few inches in thickness. Its colour is dark-blue, pale-blue, and creamy;" and in one of the darker coloured beds crinoid stems occur in great profusion. There seems no doubt that the lower portion of these rocks must correspond to some

1 "Records," Vol. XIV., pp. 305-6; Vol. XVI., p. 35, *et seq.*

part of the Kuling series of the Káshmír valley, while their higher beds correspond to a part of the supra-Kuling series of the same area. In the absence of characteristic Kuling fossils it is, however, impossible to indicate the precise limits of the two series, and the colouring on the map must accordingly be considered as purely provisional. To the north-west the Zánskár rocks have been traced to the north-east of Digi, but their north-westerly termination given on the map must be considered as merely provisional. In the neighbourhood of Himgir the limestones in place of resting upon conglomerate, are in contact with traps, also belonging to the Panjál system, and themselves followed by the conglomerate; the whole series being inverted on the north-eastern border.

Still further to the north-west, on the eastern side of the Padri pass, Col. Mc'Mahon describes a small outlier of the Zánskár rocks, resting upon the conglomerate. The former are described as consisting of about fifty or sixty feet of pale-blue limestone. Blocks of these limestones were observed in the valley between the Padri pass and Baundal, probably indicating the occurrence of Zánskár rocks *in situ* on the north-eastern side of the valley.

The correspondence of these rocks with the Zánskár rocks of the Outer Hills will be alluded to in the sequel; and it will not escape notice that the former are directly on the strike of the corresponding rocks of the Káshmír valley, indicating the south-easterly prolongation of that synclinal.

Colonel Mc'Mahon comes to the conclusion that in the Digi neighbourhood the Zánskár rocks form a highly compressed and crushed synclinal axis, the compression having been of such intensity as to produce absolute conformity of dip (isocline) throughout the

section. From the presence of trap on the north-western side of the Zánskár rocks near Digi, and its absence on the opposite side, it is considered probable by Colonel Mc'Mahon that there is a fault on the southern border of the Zánskár zone. Without, however, denying the possibility of the existence of such a fault, the present writer thinks it far more probable that the absence of the trap, both on the southern border of the Zánskár zone, and on the northern border of the same in the Rávi valley, is due to the original limitation of the area over which the trap extended.

The Chángchenmo and Kárákoram basin.

The next representatives of the rocks of the Zánskár system to be considered are those occurring in the valley of the Chángchenmo river, in north-eastern Ladákh, and such parts of the regions to the north and north-west as lie within Káshmír territory.[1] In connection with these may be noticed some outlying patches, probably belonging to the same system, in the neighbourhood of the Pángkong and Pangúr lakes. The Zánskár rocks of the Chángchenmo valley were first described by Dr. Stoliczka,[2] who recognized among them representatives both of the carboniferous and of the triassic formations: these rocks were subsequently visited by the present writer. The rocks on the left bank of the Chángchenmo river consist mainly of the slaty and trappoid rocks of the Panjál system, having a southerly dip. On the right bank, irrespective of certain patches of presumed tertiary beds noticed in a preceding chapter, there occur the characteristic white dolomites of the supra-Kuling series, containing, according to Dr. Stoliczka, numerous specimens of

1 The north-eastern frontier of Káshmír territory is indicated on the accompanying map by a dotted line (west of Kárákoram pass —.—.—.— : east of do. ....).

2 "Records," Vol. VII., p. 14. "Scientific Results of Second Yarkand Mission.—Geology," pp. 16-17.

Dicerocardium himalayense and *Megalodon triqueter*, which indicate the presence of the Pára group, although there must probably also be representatives of the underlying Liláng group. Some of the beds are hard and crystalline, while others are soft and white, like the dolomites of Amrnáth cave in the Lidar valley; they have frequently a reddish stain. Dr. Stoliczka[1] notices a semi-oolitic structure in these rocks which is said to recall a character of the so-called Krol limestone of the Simla district. These rocks dip in the opposite direction to the Panjál rocks on the left bank of the river, whence it has been inferred that the junction may be a faulted one; to the eastward of Kyám, however, there occur some shaly beds, probably corresponding to the Kuling series, and there is apparently a normal sequence of the Panjál and Zánskár rocks. To the north of the supra-Kuling rocks, in the neighbourhood of Gogra, there occurs a considerable thickness of black shales, alternating with sandstones, in which traces of fucoids have been observed. These rocks seem to be inverted on the supra-Kuling series to the south, and contain patches of the latter, too small to be shown on the map. They have been considered by Dr. Stoliczka as the probable equivalents of the Kuling series, and they are so coloured on the map; it is, however, quite possible that they may contain representatives of the Panjál system. These rocks form the crest of the Chonglung pass. To the south of that pass, and in the neighbourhood of the thermal springs north of Gogra, it appears from Dr. Stoliczka's notes that the supra-Kuling rocks are in force, but their exact limits can only be very approximately indicated on the map.[2] To the north of the Chonglung pass supra-Kuling rocks seem to occupy the whole of

1 See "Scientific Results of Second Yarkand Mission.—Geology," section on p. 16.

2 In a previous map, owing to a misconception, this band of rocks was classed as of silurian age.

the lofty plains of Lingzhíthang, and extend far to the east and west.[1]

On the extreme north of Lingzhítang in the Lokzhung mountains (lat. 35°, long. 79° to 80°), Mr. Drew[2] has recorded the occurrence of the following rocks:—"There is an older encrinitic limestone, dark grey in colour, which usually is dipping high; this makes hills not the most rugged. Ferruginous sandstone, and above that a limestone that contains hippurites, lie unconformably on the older limestone; these sometimes make isolated hills of various forms, sometimes, with a high dip of the strata, make a rugged serrated ridge. Some portion of this newer formation gives, in the weathering, a reddish-brown surface; other portions of a light-coloured limestone, or crystalline marble, make conspicuous white rocks."

From this description it is pretty evident that the crinoidal limestones correspond to some of the lower part of the supra-Kuling series; while the ferruginous sandstone and the hippuritic limestone probably represent the yellow Gieumal sandstone and the Chikkim (cretaceous) limestone, the latter according to Dr. Stoliczka[3] frequently containing hippurites (*Rudistes*). The unconformity indicated by Mr. Drew at the base of the sandstone is, however, a different condition from that prevailing in Spiti, where the Gieumal sandstone conformably overlies the Spiti shales. The position of the Lokzhung rocks is not sufficiently clearly given to have enabled their introduction on the map.

1 There is some little uncertainty as to these rocks, since in Dr. Stoliczka's notes it is first stated that carboniferous rocks "form the whole of the western portion of the Lingzithung [Lingzhíthang]" and subsequently that to the west of the same "the hills are mostly composed of the same triassic limestone." A map left by Dr. Stoliczka indicates triassic rocks in this region, and this is probably correct.

2 "Jummoo and Kashmir Territories," p. 343.

3 "Memoirs," Vol. V., p. 117.

The next position where the Zánskár rocks of this basin are known, is on the Kárákoram route from Yárkand to Leh, where they were noticed by Dr. Stoliczka immediately before his death.[1] It is stated that rocks of the supra-Kuling series are extensively developed to the north of the Kárákoram pass, where they are beyond the scope of the present memoir. At the pass itself certain greenstones are stated to be in contact with black crumbling shales, considered as of triassic age. These rocks are overlain by whitish, grey, or red limestones, followed by blackish and grey marly shales, and these by nearly horizontal beds of brown limestone, considered to belong to the lower Tágling group, and containing fragments of belemnites. These rocks extend far to the eastward, and yield the so-called "Kárákoram stones," which occur in dark shales below limestones, probably belonging to the upper trias or the lower lias (? Pára or Tágling group). These fossils have been referred to a peculiar order of Rhizopoda, under the name of *Syringosphæridæ*, of which there are two genera—*viz.*, *Syringosphæra*, with five species, and *Stoliczkaria*, with one species.[1] To the south of the pass similar rocks are described as extending on to the Dipsang plain, where they belong mainly to the lower (?) Tágling group, and thence far away to the eastward. Fragments of syenitic gneiss occurring in the streams are considered to indicate the presence of some gneissic rocks on the western watershed of these plains: while fragments of greenstone seem to indicate the occurrence of that rock *in situ* within the basin The supra-Kuling rocks were traced to a place called Burtsi, some miles below Kisilangar, where Dr. Stoliczka's diary ends. They probably, however, extend considerably further to the south, and are in connection with similar rocks on the northern side of the Sáser pass,

1 "Scientific Results of Second Yarkand Mission.—Geology," pp. 45-6.
2 *Ibid*, "Syringosphæridæ," by Professor P. M. Duncan.

described by Dr. Bellew, where they are stated to overlie the presumed Kuling rocks.[1]

The foregoing observations, imperfect as they are, indicate pretty clearly that the rocks of the Zánskár system in the Chángchenmo valley and the regions to the northward, are in direct connection with the corresponding rocks of the Sáser pass, and the districts on either side, and that they probably form one large and continuous basin. The presumed connection of the supra-Kuling series of the Chángchenmo valley with the corresponding rocks of the Sáser pass, has been conjecturally indicated on the accompanying map. The exploration of the Lingzhítang mesozoics will be a work of great interest, but from the nature of the country, one of extreme difficulty.

As outliers of the Chángchenmo basin certain rocks near the Pángkong lake, and further to the south-east, which have been provisionally referred to the Kuling series, may conveniently be noticed. At the north-western extremity of the lake, in the neighbourhood of Lukung, where the original relations of the rocks have been considerably disturbed, there occurs a great development of a pure glistening white quartzitic sandstone, or quartzite, which in its higher beds becomes gradually calcareous, and thus passes imperceptibly into a pale blue limestone. These rocks overlie the older palæozoic rocks in the neighbourhood, and may be faulted against the ridge of gneiss to the southward. They precisely resemble the lower part of the Zánskár system in the Lingti valley of southern Rupshu, and, therefore, probably correspond in the main to the Kuling series, although it is here, as there, difficult to draw an exact boundary between the rocks of the Panjál and Zánskár systems, and it is not improbable that the white quartzites at the base may correspond to

1 Stoliczka, *loc. cit.* p. 17. It is here stated that the trias of the Kárákoram overlies carboniferous rocks, a statement which was subsequently altered.

part of the Múth series of Spiti, which, as will be shown at the commencement of the next chapter, has white quartzites in its upper part.

Further to the south-east, in the neighbourhood of the Tsáka (Saki) pass, south of the Pangúr lake (lat, 33°, 45', long. 78° 107'), there occur other outliers of limestone. With regard to these rocks, Mr. Drew[1] observes, that "on the rise from the Indus to the Tsáka pass beds of blue limestone and brown shale appear dipping north-east, with granite mountains north-east and south-west of them. The pass itself seemed to be of granite [? gneiss], though, on account of debris, this was not quite clear. A little beyond the limestone again cropped out, in a patch, while some miles further to the north-west shale again appears as if it cropped out from below the granite." The shales are almost certainly the continuation of the Panjál rocks of Tánktse,[2] and it is probable that the limestones, which may well be the same as those of Lukung, form a compressed synclinal in them, inverted on the north-eastern side, where they dip under the inverted gneiss, which perhaps is of greater extent than appears on the map. If any gneiss exist on the pass itself, this must probably represent altered Panjál rocks.

The Baltistán basin.

The next examples of the rocks of the Zánskar system presenting themselves for consideration are those occurring in the area drained by the Shigar river, in upper Baltistán, which may conveniently be termed the Zánskár rocks of the Baltistán basin. These rocks rest in the middle of the great series of crystalline rocks which forms nearly the whole of Baltistán, and are generally more or less metamorphosed themselves, although in the neighbourhood of Shigar they are frequently but little altered. They are first met with on the

1 "Jummoo and Kashmir Territories," p. 314.—Note.

2 *Vide infra.*

left bank of the Shigar river, a little distance above the town of that name, and after a short course in a north-easterly direction, they sweep gradually round in an open curve to regain the normal north-easterly strike, and apparently continue in this direction beyond the limits of Káshmír territory, in the direction of the almost inaccessible states of Húnza and Nagar. In the neighbourhood of Shigar itself rocks probably corresponding both to the Kuling and the supra-Kuling series can be recognized; but in other parts of the basin only the latter can be detected, all the subjacent rocks having been metamorphosed beyond recognition. It will, therefore, be understood, that where the supra-Kuling rocks are represented as directly overlying the metamorphic series, the latter must contain representatives both of the Kuling series and of the older Panjál system.

These Zánskár rocks of Shigar were first geologically examined by Colonel Godwin Austen, who obtained, in the Bhaumaharel ravine, to the north-east of Shigar, from a limestone block fallen from the cliffs above, some imperfect specimens of a species of *Rhynchonella*; and from near the Skoro pass some remains of crinoids.[1]

The relations of the Shigar rocks may be best realized by the description of several sections taken through them. The first of these is taken down the small ravine running in a north-easterly direction from the village of Hashupa, some eight miles to the north-west of Shigar. The rocks exposed in this ravine, at a distance of about

1 It is extremely unfortunate that the labels of Colonel Godwin Austen's carboniferous fossils from the Káshmír territories appear to have become confused on their arrival at home, in consequence of which fossils from the Kuling series of the Káshmír valley were described as coming from Shigar. ("Quar. Jour. Geol. Soc.," vols. XX., p. 387, XXII., p. 39: the error is corrected on the additional page facing p. 35 of vol. XXII.) None of the fossils described in those memoirs really came from Shigar.

five miles above its mouth, consist of a series of regularly stratified beds, having a low north-westerly dip, and forming a descending series from the top to the bottom of the valley. The exposed section may be tabulated as follows, the thickness of the different beds being only a very rough approximation:—

		Feet.
Supra-Kuling series.	1. Brown, black, blue, and green shaly slates, with occasional dolomitic limestones	1,500
	2. Blue and white mottled limestones	400
	3. Black slates, with pyrite	500
	4. Variously coloured shales and partially metamorphosed limestones, with fibrous gypsum	300
	5. Flaggy gneiss, with blue and white partially metamorphosed limestone in lenticular masses	800
	6. Black shales	200
	7. White and blue limestones and dolomites, with ferruginous bands	1,000
? Kuling series.	8. Green shales (Shigar shales)	?

In this section there is no indication of any unconformity, the flaggy gneiss near the middle passing imperceptibly into the beds above and below. The dolomites and limestones, with their characteristic red stains, marked No. 7, are precisely identical with the supra-Kuling series of the Chángchenmo valley, and there seems, therefore, to be no doubt that these and all the overlying rocks should be referred to that series. The next section is taken a little further to the south-east, from near the foot of the Skoro pass down the ravine leading to the village of Khutti. In this section also the rocks have the same north-westerly dip, but there is a considerable bend in the direction of the strike at the mouth of the ravine. In the higher part of this section there occur the rocks marked Nos. 1 to 5 in the preceding section. Below the latter there occurs a thick series of limestones and dolomites, presumably the same as those marked No. 7 in the first section, the beds marked No. 6 not being recognizable. The limestones in the second section

are, however, more inclined to be mottled, and cannot be traced continuously across the intervening ridge into connection with those of the first section. These limestones contain local bands crowded with remains of crinoids, and forming a beautiful 'entrochal marble,' like the similar marbles of Europe: they are normally underlain by a thick series of black and green shaly slates, frequently carbonaceous or gypseous, and, in the latter case, very soft and friable. Occasional cherty and calcareous bands occur in these beds, and in some of the shales there is a very remarkable marbled conglomeration of exceedingly bright coloured rocks. In these shaly rocks somewhere high up on the peak named Mango-Gusor (20,635 feet) there occurs a greenish-yellow calcareous serpentine, fragments of which are found fallen into the ravines below. This rock, which appears to be similar to one from the presumed Kuling series of the upper Wardwan valley, is extensively sought by the Shigar people for the manufacturing of small cups, etc., and will be further alluded to in the chapter on economic geology.

In the lower part of the Khutti ravine the rocks consist of a hard greenish slate, probably corresponding to No. 8, passing gradually downwards into a thin band of greenish gneiss. Beneath the latter, to the eastward of Khutti, the following rocks are exposed, *viz.*:—

		Feet.
a.	Granitoid gneiss	150
b.	Blue limestones and brown sandstones, greatly indurated and contorted	500
c.	Alternations of white metamorphic limestone and dark schistose gneiss	1,000
d.	Granitoid gneiss	(?)

In passing from Hashupa round the spur, separating that place from the Khutti ravine, it is found, as already mentioned, that the limestones and dolomites marked No. 7 in the first section, do not join those of the second section, but come very abruptly to an end; dark slates and shales occurring on their line of strike. It is

possible that this interruption may be due either to a thinning out of the calcareous rocks, or to a dislocation of the strata. In the Bhaumaharal ravine, to the north-east of Shigar, the shales marked No. 8 in the first section, which attain a very considerable thickness, rest upon a massive granitoid gneiss, in place of upon the various beds mentioned as occurring to the eastward of Khutti.

To the north-west of Hashupa the gneiss marked No. 5 in the first section gradually increases in thickness, so that at some distance above that place none of the underlying limestones are exposed,—the gneiss coming down to the very base of the section. A little below the village of Kashumal (at a place not marked on the accompanying map, called Sildi), the gneiss is again underlain by the No. 7 limestones and dolomites. Above Sildi the relations of the rocks are very obscure, but it is probable that the foliated gneiss, which is the prevailing rock, contains representatives of all the beds below No. 7, (8, *a.* *b.* *c.*) indicating that the supra-Kuling rocks probably rest in a synclinal.

To arrive at any satisfactory conclusion as to the age of the rocks below No. 7 is very difficult, and in fact almost impossible, owing to the degree to which metamorphic action has been carried. The presence of a great series of shales at the base of strong limestones and dolomites is, however, indicative of the presence of the Kuling series, and it has accordingly been thought not improbable that the shales marked No. 8, extending to the north-east of Shigar, are the representatives of those rocks, and they are accordingly provisionally so coloured in the map. If this determination be incorrect, they must be referred to some part of the supra-Kuling series; but they undoubtedly belong to the Zánskár system.

With regard to the rocks marked *a.* *b.* and *c.* in the second

section there is still greater uncertainty, as it is doubtful whether they belong to the Zánskár or to the Panjál system. The greenish gneiss above these rocks is almost certainly an altered part of the Shigar shales. Both the beds *a. b.* and *c.* and the Shigar shales to the north-east of that place, rest upon granitoid gneiss, and it is therefore possible that the former may be the altered representatives of the latter, with the calcareous bands more developed. It is, however, more probable, as will be shown below, that the Shigar shales rest uncomformably both upon the beds *a. b.* and *c.*, and upon the granitoid gneiss to the north-east. In view of the uncertainty as to their age, the beds marked *a. b.* and *c.* have in the map been coloured uniformly with the great metamorphic series.

The Zánskár rocks of the Shigar valley continue across the ridge on which is situated the Skoro pass, and may now be noticed in the valley of the Bráldu river, where they are found apparently resting in a crushed synclinal of the gneissic rocks to the eastward of Askole. At the latter place there are foliated gneissic rocks, with occasional calcareous bands, having a regular easterly dip: the gneiss is frequently crowded with blood-red garnets, and a short distance to the eastward there are some crumbly kyanite schists. About three miles from Askole this gneissic series is conformably overlain by rocks unmistakeably belonging to the supra-Kuling series, the passage from the one to the other being an imperceptible one. The section shows at first thin beds of calcareous rocks, alternating with the gneiss; gradually the limestones and dolomites become more and more preponderating, until at a halting-place, termed Kurophon,[1] these rocks are at least 1,500 feet in thickness: this thickness is, however, merely local, the beds thinning out rapidly on either side. Many of the limestones and dolomites have been but slightly

1 Not marked on the accompanying map.

affected by metamorphic action, while others have been converted into a completely crystalline rock; some of the lower beds contain in abundance long, slender, transparent crystals of actinolite, of a green or blackish colour. In the Palma (Punmah) and Baltoro valleys thin-bedded and highly metamorphic limestones alternate with foliated, and frequently garnetiferous, gneiss; the whole series showing signs of having been greatly disturbed, and being interpenetrated by numerous granitic intrusions in which hornblende is abundant. On their easterly border these Zánskár rocks appear to dip beneath the gneiss, but it is probable that all the rocks are here inverted, and that the former originally rested in a synclinal in the gneiss. No recognizable traces of the Kuling series can be detected, although it is not impossible that the above-mentioned kyanite schists, to the eastward of Askole, may be their representatives.

As already said, the strike of the Zánskár rocks bends round to the normal Himalayan direction north of the Bráldu river, and these rocks appear to continue, parallel to the Biafo glacier, to the watershed between the drainage areas of the Indus and the rivers of Turkistán.

At Chitran, on the Básha river, there is an outlier of the calcareous supra-Kuling rocks, resting on the gneiss. In the valley of the Sháyok at the village of Muchilu, some distance above Khapalu, there occur some slightly metamorphosed rocks which are provisionally referred to the Zánskár system. On the right bank of the Hushi stream at Muchilu, these rocks consist of a series of purple and green slaty shales, blueish white limestones, and fine-grained buff sandstones; their lower beds passing downwards into a greenish foliated gneiss. They have a westerly dip towards the cliffs of porphyritic granitoid gneiss on the right bank of the

stream, but their relations to this are so concealed by debris that it is impossible to arrive at any satisfactory conclusions regarding this point. These Muchilu rocks present a great general resemblance to the rocks at Shigar, referred to the lower part of the Zánskár system, and are most probably the same.

On the road from Skárdu to Deosai, to the north of the Burji pass, there occurs an ellipsoid of the rocks of the Panjál system, containing in its centre shales similar to those of Shigar, with here and there small outliers of the calcareous rocks of the supra-Kuling series, too small to be indicated on the accompanying map.

The basin of the Outer Hills.

It has already been observed in the preceding chapter that the representatives of the Zánskár rocks in the region of the Outer Hills occur partly on what is considered to be the northern boundary of the basin, and partly as outliers in its centre; the southern boundary of the presumed basin being buried beneath the tertiary rocks and the alluvium of the plains of the Punjab. In the identification of these rocks, except in one doubtful instance, fossil evidence is not available, and everything has, therefore, to depend upon petrological resemblances, or stratigraphical position. The evidence afforded by these is, however, so strong as to leave no doubt that these rocks really belong to the Zánskár system.

In describing these rocks, the band situated on the inner boundary of the tertiary rocks will first be described, and subsequently the outliers in the middle of the basin. Commencing with the former in the valley of the Jhelam above the village of Uri, it will be found that on leaving the tertiaries, the first beds met with consist of schisty shales and limestones; the former are either red, green, or black, in colour, and are frequently soapy to the touch,

indicating a magnesian element; some of the green shaly beds contain lenticular cherty concretions. These mixed beds are succeeded by a dark blue slaty limestone, passing gradually up through some dark shales into slates and sandstones of a blackish colour. All these rocks appear to conformably overlie the tertiary beds, and to underlie the Panjál rocks of the range of that name; the whole series being presumed to be inverted. Mr. A. B. Wynne has obtained from the limestones at Uri a few indeterminable specimens of small spiral gastropods.

To the north-west of Uri these rocks can be traced for a distance of some fifteen miles, beyond which the Panjál rocks come into direct contact with the tertiaries. To the south-east the same rocks may be traced continuously along the inner tertiary border (being, as on the road from Púnch to the Pír-Panjál pass, occasionally repeated by a dislocation [1]) to the point where the Chínáb leaves the region of the Middle Mountains, where they are interrupted for a short distance. In this neighbourhood an instructive section of these rocks has been taken near the village of Kiol,[2] on the upper part of the Ans river, a tributary of the Chínáb, joining it to the north of Riási. The section is presumed to be an inverted one, and has, therefore, been reversed in the following table:—

Zánskár system	1. Purple, or white, fine-grained glistening quartzites, top not exposed.
	2. Black shales, containing thin strings of coaly matter, and ferruginous nodules, locally passing into black slates.
	3. Dark blue fetid earthy limestone, with bands of carbonaceous shales, and passing gradually down into
Panjál system	4. Amygdaloidal and slaty rocks.

1 The limestones in this district were originally considered by Colonel Godwin Austen as nummulitic.

2 This village is not marked on the accompanying map, but is shown on the larger Indian atlas. The name of this place was formerly applied locally to this group of rocks, but may now be superceded by a more general one.

In this section the rocks marked No. 4 are certainly those of the Panjál system, which in the Káshmír valley underlies the Zánskár rocks; and it is mainly from this relationship, coupled with the general resemblance of the limestones and shales of Uri and the Ans river to the Zánskár rocks of the Káshmir valley (a resemblance which will be more fully noticed below), that the former are referred to the Zánskár system.

To the south-east of the Chínáb valley, the band of limestone and shaly rocks is again met with, and is continued, after a marked bend in the valley of the Rávi, along the south-westerly flank of the Dhauladhár range, through the outer side of Chamba territory, to the limits of the area forming the subject of the present memoir. In the neighbourhood of Dalhousie these limestone and shaly rocks, according to the description of Colonel Mc'Mahon,[1] are underlain on their outer, or western, border by a band of the amygdaloidal traps of the Panjál system. "The rock immediately in contact with this trap along its eastern boundary is a quartzite, for the most part of white colour, as trans-Rávi near Kairi.[2] Then follows a thick series of shales and limestones, until the gneiss, which bounds this series on the east, is reached. Next the gneiss the rocks consist of a dark micaceous slate, something between a shale and a schist, which disintegrates into a black "crush rock," exactly similar to the "crush rock" of the Simla area. A good and extensive example of this rock may be seen on the descent from Dalhousie to Sherpur (Sairpúr). It is here, especially when wet, almost coal black. *This dark slaty rock is not confined to the eastern boundary of the series. I have also seen it at or*

1 "Records," vol. XV., p. 36, *et seq*, and map facing p. 50.

2 Two places of this name occur in this district, one which is given on the map accompanying this memoir, near Basoli, and the other, which is alluded to in this passage, on the bend of the Rávi due north-west of Sairpúr.

near the western boundary, as in the river bed trans-Rávi, north of Kairi.

"Occasionally limestone is seen within a few yards of the gneiss, and apparently in actual contact with it. An instance of this may be seen in the Chuári [Chaohari] section, where the limestone, which is as usual of dark blue colour, is sub-crystalline and contains cubes of iron pyrites.

"One of the best sections of the limestone series is, I think, to be obtained on the descent from Dalhousie to Sandára. The gneiss is left a little to the east of Dhalóg; then succeed the dark carbonaceous slates, which exhibit a hypometamorphism in the shape of micaceous glazing. Between this and the quartzite in contact with the trap, I counted four strong outcrops of dark-blue limestone, intercalated with blue slates. The limestone is in bands of from 200 to 250 feet broad, and in beds that rarely exceed two inches in thickness.

. . . .

"The limestone series, as a whole, dips into the gneiss all along the line.

"I think the carbonaceous slaty rocks above described, which disintegrate under the action of water into black "crush rock," are identical with the "*infra*-Krol" slates of the Simla region, which, even in that area, contain "lenticular layers of limestone.""

It is somewhat difficult to bring the foregoing section into exact accord with the section on the Ans river, and this is the more difficult since the present writer has never visited the Chamba district. On the assumption that the section on the Ans river is an inverted one, which is almost certainly the case, and since the dip of all the rocks in the Dalhousie section is in the same direction, the

presumption becomes very strong indeed that there is also some inversion in the latter, although this is considered unlikely by Colonel Mc'Mahon. The undoubted existence of inverted strata in the Chamba valley appears to support this view. The presence of the band of Panjál trap on the western border of the limestone and shaly rocks of Dalhousie leads, however, to the conclusion that on this side at least the section is in normal order,—a conclusion shared by Colonel Mc'Mahon. The presence of this trap on one side of the limestones, and of gneiss on the other leads, moreover, to the further conclusion that a fault must probably occur on one side or the other, and from the above-mentioned relation of the trap to the limestone and shaly rocks, it is apparent that this fault, if it exist, must occur on the eastern, or inner, border of the latter, at their junction with the gneiss. The existence of this fault is considered probable by Colonel Mc'Mahon, who also believes in the existence of a second fault on the western border of the main crystalline mass.

According to this view the whole of the strata between the middle of the zone of limestone and shaly rocks, and the middle of the granitoid rocks of the Dhauladhár range have been originally thrown into a series of folds, and inverted on one of the sides of each fold. A subsequent fault has disturbed the inner border of the zone of limestone and shaly rocks, and partially destroyed the symmetry of the original synclinal.

As confirmatory of this view the fact recorded by Colonel Mc'Mahon (italicized in the foregoing extract) may be mentioned that distinct traces of carbonaceous rocks like those on the eastern border of the limestone and shaly zone, and similar to the infra-Krol rocks, occur also on the western border, close to the trap.

It is true that Colonel Mc'Mahon considers[1] that these beds are not repetitions of the same, but belong to different horizons; but it is equally allowable to adopt the former view. The slight development of these carbonaceous rocks next the trap is very similar to the condition which has been shown to be of constant occurrence in the Káshmír valley, where the trap is supposed to have been poured out at the time of deposition of the shales, and to have obliterated them. On this view the trap is considered never to have occurred on the eastern border of the limestone and shaly rocks. The apparent occurrence of the quartzite on the top of the shales only on the western side of the series is indeed a difficulty, but Colonel Mc'Mahon himself thinks that the degree of development of these rocks may have locally varied considerably. In the Ans river section the quartzite is placed at some distance above the traps, and it is probable that its place on the eastern side of the Dalhousie limestones should be above (or, to the westward of) the carbonaceous rocks, and not below them as might at first sight be thought probable, from the relation of the traps to the quartzite on the western side. It is quite possible, however, that the carbonaceous shales on the eastern side may have been developed to the exclusion of the quartzite; while the apparent absence of both of these rocks in the Zánskár system of the Chamba valley, indicates how little constant their development seems to be.

It is assumed in the above interpretation, following Colonel Mc'Mahon, that the two bands of gneiss belong to the same horizon; but this point, and the relations of the Panjál rocks will be again touched upon in a subsequent chapter. It would of course be presumptuous on the part of the present writer to say positively that

1 "Records," Vol. XV., pp. 37-8.

the foregoing explanation of the relation of the Dalhousie rocks is the true one; but it may be safely affirmed that if some such explanation could be adopted, it would bring the section far more into accord with the analagous one to the north-west than is the case, according to Colonel Mc'Mahon's interpretation.

On the northern side of the Rávi the whole of the zone of Panjál traps is absent, and the tertiary rocks of the Murree group, having a dip to N. 11° E., "are followed by a massive quartzite of whitish colour, dipping east, and then by the slates and limestones of the carbo-triassic series [Zánskár system], which have also an easterly dip. The limestones are the ribbed variety previously described, and they continue to the top of the Banjál pass [leading into the Siava valley] . . . . . At the top of the pass the rocks dip S.W. 11° S., but the dip is high and nearly vertical. The carboniferous slates become very black as the gneiss is neared." It is obvious that the interpretation of the relations of this section must be the same as that of the last: the signs of a westerly dip near the gneiss may perhaps be considered as indicative that the strata originally occupied a synclinal.

To the south-eastward of the valley of the Rávi the limestone and shale series is continuous with the typical examples of the Krol and infra-Krol groups of Mr. Medlicott, in the Simla and neighbouring districts,[1] and there is, accordingly no doubt but that the limestone and shale series skirting the foot of the Middle Mountains between the Rávi and the Kishanganga valleys, corresponds to some portion of these two groups. In the Dalhousie section it has been shown that certain carbonaceous rocks, here considered to be near the base of the limestone series, correspond in all probability to the

1 See map accompanying "Memoirs," Vol. III., pt. 2.

infra-Krol group of Simla. Whether the strong limestones of the Dalhousie section correspond to the Krol series, or must be considered as part of the infra-Krol, must depend on the manner in which that section is interpreted: in petrological characters they agree best with the former.[1]

With regard to the typical development of these rocks in the Simla district, it may be observed that Dr. Stoliczka[2] considered it highly probable that the Krol limestone corresponded to the Liláng group of Spiti; but he was unable to identify the infra-Krol group with any of the Spiti rocks, although he considered that it presented a great resemblance to the lower trias of the Alps. It was at the same time suggested that the Kuling series of Spiti might be represented by certain quartzose and micaceous beds in the Simla district.

Now since it has been shown that in the Dalhousie district the limestone and shale series conformably overlies rocks precisely similar to the rocks underlying the Zánskár rocks of Káshmír, and that the Dalhousie limestones, etc., are the equivalents of some part of the united infra-Krol and Krol groups, it may be taken as proved that the two latter groups correspond to the Zánskár system of the inner districts of the Himalaya. If additional proof of this identification were required, it might be found in the resemblance existing between the limestones and shales of the Jhelam valley, and the typical Zánskár rocks of the lower Kishanganga valley, and of the Lidar valley in Káshmír proper. The great resemblance, in regard to their oolitic character, of the Zánskár limestones of the Chángchenmo valley to

1 Colonel Mc'Mahon (*l. c.*, p. 37) is inclined to correlate all these rocks with the infra-Krol, or carboniferous: this is, however, inevitable from his point of view.

2 "Memoirs," Vol. V., p. 141.

the Krol limestone is another confirmatory instance mentioned by Dr. Stoliczka.

In the Outer Hills it is obvious that at the base of the Zánskár rocks the representatives of the Kuling series of the Káshmír valley must occur wherever the whole series is present. The presence of a strong carbonaceous element is very prevalent in the infra-Krol group of Simla,[1] and in what are here regarded as the basement beds of the Zánskár rocks of the Dalhousie district, and in the corresponding rocks on the Ans river: quartzites also occur locally in all these rocks. It will be remembered that in the Káshmír valley the Kuling series is characterized by a similar preponderance of a carbonaceous element, with a locally well-developed quartzite, the whole series being overlain by strong limestones. It, therefore, seems highly probable that the Kuling series corresponds approximately to the infra-Krol group of the Simla district, and, therefore, also to the lower part of the Zánskár system of the Outer Hills to the north-west of the Rávi valley. The Krol group of Simla will then approximately correspond, in accordance with the views of Dr. Stoliczka, to part of the supra-Kuling series of the inner Himalaya. Within the limits of Káshmír territory, it is at present impossible to correctly subdivide the Zánskár rocks of the Outer Hills in correspondence with these groups. Since, however, in the Káshmír valley, the Kuling series is of extreme tenuity, it seems probable that representatives both of the Kuling and the supra-Kuling series may often exist in the zone of Zánskár rocks at the foot of the Middle Mountains. Accordingly, where this band of Zánskár rocks is strongly developed, the higher beds have generally been coloured in the map as belonging to the supra-Kuling, and the lower to the Kuling

1 "Manual," pt. II., p. 600.

series. This division must, however, be considered as a purely provisional and arbitrary one, and it would have been better, if practicable, to have coloured all these rocks of the same tint: this would, however, have involved the greater difficulty of not indicating their agreement with the two divisions of the Zánskár rocks of the Káshmír valley and other parts of the inner Himalaya. On the outer flank of the Dhauladhár range the whole of the Zánskár rocks have been coloured in as belonging to the Kuling series, although, as already said, it is quite possible that the supra-Kuling series may also be well represented. Since, however, as has been already shown, there is a very considerable degree of uncertainty as to which are the higher beds of the series in that district, it has been thought better not to attempt any division. If the view entertained above be the correct one, then the middle portion of the zone of Zánskár rocks in this district will be the equivalent of the supra Kuling series, if any representatives of those rocks are present.

The next rocks for consideration are the extensive inliers of old limestone occurring within the tertiary area of the Outer Hills, which were first brought to notice by Mr. Medlicott, who described them under the provisional name of the "Great Limestone."[1] Commencing on the outer border of the Sirmúr zone, these rocks are described as forming one broken inlier, which makes its first appearance at Dándli, on the Púnch river, a few miles to the north of Kotli, and disappears some eighty miles to the south-east, at a point about seven miles to the north-west of Udampúr. "It is not continuous throughout this distance, as there is no sign of it in the valley of the Bari-Tawì [Tavi] between Naushahra and Rájáori; but all the outcrops occur along the same line of flexure and upheaval. It is

1 "Records," vol. IX., p. 53.

noteworthy that this line is on the general extension of the middle tertiary break of the Simla region,—the outer boundary of the Sirmúr zone. The principal mass of limestone is at the south-east end, where for a length of thirty miles it forms a lofty picturesque ridge, through the very centre of which the Chínáb has cut a precipitous gorge, just north of Riási. The structure of this feature conforms throughout to that which is so dominant over the whole south Himalayan region,—a normal anticlinal flexure, broken and faulted on its steep outer face. Besides this familiar transverse structure, the clearly defined outcrop of these groups betrays a regular longitudinal waving of the stratification. . . . . . . The great limestone itself is a dense crypto-crystalline rock, in this respect contrasting strongly with the compact and often earthy nummulitic limestone close above it. It is often thin-bedded, locally cherty, and occasionally has intercalated bands of silicious slates and flags. The aggregate thickness of the mass must be great." No traces of fossils have been yet met with, and there is no striking resemblance to the Krol limestone. The relations of these rocks to the tertiaries have been discussed in a previous chapter.

Another inlier of this limestone occurs in the Chínáb valley, some miles below the Ramban (Ramband) bend, and extends to the north-west into the valley of the Ans river: it appears to occur on the line of a broken anticlinal. The limestones of this inlier are entirely thin-bedded, and lack the massive appearance of the outer inlier: they present a characteristic banded appearance. The dip of these limestone rocks is to the north-east, and on their inner border they are succeeded normally by the rocks of the Murree group, with indications of local faulting. The upper beds of the limestone are thin-bedded, and light-coloured, with a very characteristic banded

appearance. What has been supposed to be the impression of a *Fenestella* has been detected in these rocks.

Although the limestones of the outer inlier are more massive, yet the banded rocks of the inner inlier are precisely similar to the rocks of the supra-Kuling series of the Káshmír valley, and it is, therefore, considered that the two are in all probability identical. The limestones of the Káshmír valley, as already noticed, are frequently totally unfossiliferous over extensive areas, and thus present no dissimilarity in this respect to the great limestone of the Outer Hills.

The reference of the latter to the upper part of the Zánskár system, and of the greater portion of the Uri limestone and shales to the lower part of the same system, accords exactly with the characters presented by those rocks in the Káshmír valley, where carbonaceous shales and quartzites are the predominating element in the Kuling series, and strong limestones and dolomites in the supra-Kuling series. If these identifications be correct the great limestone will, in opposition to the original view of Mr. Medlicott, be the same as the Krol limestone: the difference in the petrological characters of the two are not greater than that which occurs between some of the supra-Kuling rocks in the Káshmír and Zánskár basins.

Khágán valley.

In connection with the Zánskár rocks of the Outer Hills it will be convenient to notice their probable representatives in the Khágán valley. In various parts of that valley, above the area occupied by the tertiary rocks, the more or less completely metamorphosed palæozoic rocks are overlain by patches of carbonaceous and pyritous shales, which have also undergone a partial metamorphism; and these again by a hard white, or buff, highly crystalline, metamorphic limestone,

or marble. On the left bank of the river below the bend, at the village of Chulgrám, these limestones are folded in between the older palæozoics, and, as in other places in the neighbourhood, the underlying shales have been altered beyond the possibility of recognition. The close resemblance of these rocks, whose distribution is approximately indicated on the accompanying map, to the metamorphosed Zánskár rocks of parts of the Kishanganga valley, and also to their unaltered representatives in the Káshmír valley, as well as their relations to the underlying rocks, leaves little room for doubting that they are the representatives of the same great system. The carbonaceous shales, where they can be detected, may probably be regarded as the representatives of the Kuling series, and the overlying limestones of the supra-Kuling series. Where the former, owing to metamorphic action, cannot be detected, it has been found necessary on the map to represent the supra-Kuling series as being in contact with the metamorphic rocks, but the Kuling series must of course be represented among the latter.

The Zánskár rocks of Khágán, are merely outliers of the mesozoic rocks of the Hazára district,[1] where the trias corresponds, in the main with the lower portions of the supra-Kuling rocks of Káshmír territory. The trias of Hazára is underlain by beds known as the infra-trias and the Tanol group, which have probably some affinity to the Kuling series of Káshmír, though they appear to be considerably thicker, and may possibly contain representatives of part of the Panjál system. For further details respecting the correspondence of the Káshmír and Hazára rock-series the reader may consult a recent paper by Mr. A. B. Wynne.[2]

1 See "Records," Vol. XII., pp. 114, 208, and "Memoirs," Vol. IX., article 3.
2 "Records," Vol. XV., p. 164.—"Further note on the Connexion between the Hazára and Káshmír series."

Former union of areas of Zánskár rocks.

The position of the Zánskár rocks in the various areas in which they have been described, is always that of an ellipsoidal basin, with its longer axis coincident with the general direction of the strike of the Himalayan rocks, and it may, therefore, be assumed with fair certainty that these basins are basins of disturbance. Had they been basins of original deposition, their directions would probably have borne a more or less well-marked conformity to the direction of the existing river valleys, which is certainly not the case with their present distribution. The numerous small outliers, the absence of 'overlap,' and the general concordance in the petrological characters of the rocks of the system over very extensive areas, all point to the former continuity of the areas in which the Zánskár rocks were deposited. "The only appearance of an original basin, corresponding with the actual one, is in the upper secondary deposits—the Spiti and Chikkim groups; and even for these the case is not very evident. The best case quoted is that at Múth, where the carboniferous (Kuling) group seems to be regularly overlapped by the Liláng beds; but this, like the two cases just mentioned, only points to a southern limitation of the Himalayan deposits."[1] In the Káshmír area even the latter boundary shows no signs of existence, if the views entertained above are correct, as it must be supposed that Zánskár and the older palæozoic rocks are extensively developed beneath the plains of the Punjáb; the latter probably continuous with those near the lower Indus valley, which will be alluded to below. It remains for future geologists to work out the exact geological age of the upper Zánskár rocks in the Káshmír basin, before the relative date at which the various existing basins of these rocks were formed can be determined.

1 "Manual," pt. II., p. 643.

Although the foregoing views seem to be probable, it must not be omitted from mention that Dr. Stoliczka appears to have come to the conclusion that various well-marked breaks occurred in the deposition of the rocks of the Zánskár system. One of these breaks is supposed to have occurred at the conclusion of the carboniferous, and another at the close of the triassic period: and it is stated that after the latter "large tracts of the country were raised, and never more covered by the sea, until partially in comparatively recent periods, (eocene), while in other places the regular succession of deposits took place."[1] In regard to these points the present writer is fain to confess that he cannot gather, either from his own observations, or from those of Dr. Stoliczka, evidences of extensive disturbances either at the close of the triassic, or of the carboniferous period. From the non-detection of the higher jurassic and cretaceous deposits in so many parts of Káshmír territory, it is, however possible that much of that area has never been submerged (except locally in tertiary times) since some part of the jurassic epoch.

In conclusion, there remains one point regarding the relation of the tertiaries to the older rocks of the Dalhousie district which may conveniently be noticed here. It will be remembered that in an earlier chapter[2] it has been thought probable that on their inner border the tertiaries were originally deposited parallel to the older rocks and have subsequently been inverted beneath them. If this relation hold good in the Dalhousie district (and the parallelism and direction of the dip of the rocks indicates that it probably does), it follows that the outer border of the pretertiary rocks forms a compressed anticlinal, with the outer side inverted. This presumed fold south of the Rávi would be situated in the trap, while north of the same it

1 "Manual," pt. II., p. 642. 2 p. 95.

would run on the outer border of the Zánskár rocks, and further to the north-west would merge in the one great inverted fold into which all the strata seem to have been squeezed. It should be added that Colonel Mc'Mahon considers the junction between the tertiary and older rocks a faulted one,[1] but this is necessary from his point of view: it is not impossible that as an accessary to the main relations of the feature local faulting may occur in the Dalhousie district.[2] It was not thought advisable to introduce an argument from the relation of the tertiaries to the older rocks to confirm the existence of folding and inversion in the Dalhousie district, but it is manifest that if their relation be the one indicated above, folding and inversion must have taken place.

1 See map facing p. 60 of "Records," Vol. XV.

2 This is perhaps confirmed by a cutting-out of the inner tertiary zone to the south-west of Chaohari indicated in Col. Mc'Mahon's map. This cutting-out, in view of certain discrepancies between that map and a manuscript map of Col. Mc'Mahon's, has been omitted in the map accompanying this memoir.

CHAPTER VIII.—THE PANJÁL SYSTEM; OR OLDER PALÆOZOIC (SILURIAN AND (?) CAMBRIAN) ROCKS.

Equivalent deposits: the Panjál range and the Káshmír basin: the Chamba basin and the Dalhousie district: the Zánskár basin: the Chángchenmo basin and Ladákh range: Baltistán: Summary.

Equivalent deposits.

Before proceeding to the description of the Panjál, or older palæozoic, rocks of Káshmír territory, it may be well to mention briefly the older palæozoic rocks of Spiti and the Simla district. In the former area Dr. Stoliczka recognized two great series of partly fossiliferous rocks lying between the Kuling series and the central, or archæan, gneiss. These two series are characterized as follows by Dr. Stoliczka,[1] *viz.*:—

1. "*Múth series*, probably of silurian age, and consisting of three different groups of rocks, the lowest of which are purple quartzites, the middle arenaceous limestones, and the upper white quartzites. In the middle series [group] *Orthis*, *Strophomena*, and *Tentaculites* have been observed. [In a later paper[2] this series is alluded to as of upper silurian age.]

2. "*Bhábeh series*, probably lower silurian, consisting of sandstones, slates, and quartzites, with species of *Orthis* and *Chætetes yak*, Salter." This series is divided into three groups,[3] the two highest of which are fossiliferous, whilst the lowest is totally azoic,

1 "Memoirs," vol. V., pp. 134-5. 2 *Ibid*, p. 337
3 *Ibid*, pp. 17-18.

and its basement beds are micaceous, and rest upon foliated gneiss, passing downwards into granitoid gneiss. It was suggested that the lower azoic group might eventually be referred to a distinct series. In the later paper quoted above the Bhăbeh series is referred to as of lower silurian age.

The thickness of the Múth series is estimated at from 1,000 to 1,300 feet, and that of the Bhábeh series at more than 3,000 feet.

In the sequel these rocks will generally be alluded to as of upper and lower silurian age for the sake of convenience. It must, however, be borne in mind that as they are succeeded by rocks with a lower carboniferous fauna it is quite possible that they may partly correspond in time to the devonian system, although no fossils characteristic of the latter have hitherto been detected in the Himalaya. Similarly the lower azoic group of the Bhábeh series may very probably correspond to the cambrian of Europe.

In the Simla district the non-metamorphic rocks below the infra-Krol group, which in the preceding chapter has been provisionally correlated with the Kuling series, likewise consist of two series, the description of which is taken from the "Manual."[1]

1. *The Blaini series.* "This group [or series] consists of two very distinct members, each of which seldom exceeds 50 feet in thickness, and is generally much less. The upper rock is a fine, compact or micro-crystalline magnesian limestone, of pale-grey and pink tints, thin-bedded, but often amalgamated into a single mass. It rests upon a quartzitic sandstone, often a clear quartzose rock, but sometimes rusty and more or less earthy. In whole or in part this lower band is very often highly conglomeritic, with well-rounded

1 Pt. II., pp. 599, 600.

pebbles and small boulders of white quartz and variously tinted quartzites, and sometimes partially-rounded debris of slate rocks. Pebbles of crystalline rocks have not been observed in it in this region."

2. *The Infra-Blaini series* (Simla slates). These rocks "consist of finely laminated slaty shales and thin sandy flagstones, with occasional beds of earthy sandstones." They are estimated to be at least 5,000 feet in thickness. Their base is not known in the typical Simla region.

Dr. Stoliczka[1] thought it highly probable that the Blaini series might correspond to the Múth series; and the infra-Blaini series to the upper part of the Bhábeh series, the middle and lower part of the latter being not improbably represented by certain partially metamorphic rocks occurring in some parts of the Simla dtstrict. Following this identification Colonel Mc'Mahon[2] has thought it probable that the infra-Blaini series, or Simla slates, may be of middle silurian age, and some of the schistose rocks which often underlie them of lower silurian age. There is, however, some uncertainty as to the age of these schistose rocks.

The Panjál range and the Káshmír basin.

The name of the Panjál system (formerly series) was originally applied to the great slaty and volcanic series of the Káshmír valley by the present writer in 1878,[3] and although it has been somewhat disused in subsequent papers, yet a local term is on the whole so convenient, that in the present memoir it will be employed to denote all the rocks below the Kuling series, and above the metamorphics. In many cases, however, a considerable part of the latter rocks will

1 "Memoirs," vol. V., p. 141. 2 "Records," vol. XIV., p. 309.
3 "Records," vol. XI., p. 34.

be shown to be the altered equivalents of the Panjál system, but as it is in general very difficult to satisfactorily distinguish these altered rocks from an older gneiss, it has been found more convenient to treat of all the metamorphic rocks in a separate chapter. It will obviate repetition to state here that wherever the whole of the older palæozoic and subjacent rocks are found in normal sequence, without inversion, the slaty rocks are always underlain by distinctly metamorphic rocks, and that no instances are known where unaltered slates are normally overlain by completely metamorphic rocks. In the words of a very able observer of Himalayan rocks, the great point to keep in view in the interpretation of the relation of these rocks is "the principle that, as a general rule, the extent of metamorphism affords an indication of the relative age of ancient rocks." This principle must, however, of course be strictly confined to the rocks of each particular area, as it has been already shown that sometimes the metamorphic action has extended up into the mesozoic rocks. In these instances, however, all the subjacent rocks have been still more completely metamorphosed. Whenever, therefore, among the rocks of the Panjál system, metamorphic bands are found apparently interstratified among unaltered slates it will be taken for granted that either a fault, or a crushed up anticlinal axis, exists among these rocks, and that the metamorphic rocks really form the base of the whole series. It will be found in most cases that this view is confirmed by the relations of the other rocks to those of the Panjál system.

The whole of the strata referred to the Panjál system throughout the countries forming the subject of this memoir are totally devoid of organic remains, with the possible exception of some obscure impressions from one locality which it has been thought might belong to graptolites. This absence of organic remains renders it necessary

to depend entirely on stratigraphical and petrological evidence in the identification of the rocks of this system in different parts of the area under consideration: and in some cases this kind of evidence is at the best but uncertain. The same absence has likewise at present forbidden the general division of the system into its component members, though there are not wanting indications that certain petrological zones are in many cases of sufficient constancy to afford grounds for some such division.

It may not be out of place to mention here the extraordinary absence of fossils in so many of the Himalayan formations, which from their lithological characters might have been thought highly favourable to the conservation of organic remains. This absence is equally noticeable in the Panjál slates, and in the Sirmúr tertiaries, although the ferruginous element may have been the preventive cause in the latter case. The Zánskár limestones of the Outer Hills afford another equally remarkable instance.

The description of these rocks may be commenced in the Pír-Panjál range, whence they derive their name, and they will be described here and in the Káshmír valley more fully than in other regions.

In the valley of the Jhelam from Uri to Báramúla, where it cuts completely through the Panjál range, after leaving the Zánskár rocks of Uri, already described, flaggy slates, sandstones, and grits continue the whole way: the dip is generally to the north-east, but is much obscured by folds and contortions. South of Gingal some of the beds have a partially schistose structure, and occasionally approach very closely to gneiss; above that place the strata consist of thick-bedded flaggy slates, placed nearly vertically, and forming stupendous, inaccessible cliffs. Boulders of porphyritic granitoid gneiss occur in

great quantities in the bottom of the valley, but are not seen *in situ*, being derived from the lofty peaks on either side.

Another section taken across the range from the summer station of Gúlmarg, in the Káshmír valley, over the Nílkanta pass, exhibits a very similar series of slate and sandstone rocks, with a local tendency to a schistose structure in the heart of the range. South of the pass the rocks all dip towards the heart of the range, their exposed edges forming an extraordinarily steep escarpment to the south. No traces of the above-mentioned granitoid gneiss are to be met with on this line. Along the foot of the range in the Káshmír valley, in the neighbourhood of Báramúla the rocks consist of blackish slates, and of green, or greyish, sandstones, with some bands of white quartzite. Near Gúlmarg amygdaloidal trappean rocks are largely interstratified with the sedimentary rocks, and continue thence along the whole of the foot of the range, but gradually die out to the south-east of the Káshmír valley. All the rocks on this flank dip towards the valley, or to the north-east.

Another section across the range has been taken along the line of the old Moghul road across the Pír-Panjál pass from near Shapeyan to the district of Rájáori. A little above the village of Hirpúr, near Shapeyan, the older rocks appear beneath the superficial karewa deposits, and consist of greenish amygdaloidal volcanic rocks passing insensibly into, and interstratified with black slates, having a north-easterly dip, with here and there a fold in them. There is from this point a continuous descending series of slates and sandstones, mingled with a few bands of conglomerate, containing slate and quartzite pebbles, till some distance below Aliabád-Sarái, where these rocks are underlain by white or buff quartzites. Near that place the quartzites are in turn underlain by black slates, containing

here and there pebbles or boulders of gneiss and other rocks. Immediately above the sarái there is a band of imperfectly granitoid fine-grained gneiss, with a few bands of schists and quartzites, underlying the black schisty slates. This gneiss continues nearly to the summit of the pass, where it is in almost vertical beds, and close to the pass itself is underlain by the black slates with pebbles and boulders, and these again by whitish quartzites, forming the crest of the pass. On the southern side of the pass there is a steep escarpment formed of very similar rocks to those on the northern side, having the same north-easterly dip, and apparently underlying the quartzites and gneiss. The conglomerates which occur above the middle of the series are, however, much more developed on the southern than on the northern side, forming solid beds of at least fifteen and twenty feet in thickness. These slates and conglomerates continue, with some flexures, nearly to the village of Baramgala where they are interstratified with the amygdaloidal traps, which are succeeded by the zone of Zánskár rocks already described.

From this description it will be apparent that on the north-east side of the range there occurs a series of rocks overlying the gneiss forming the core, which is repeated in the reverse order on the opposite side. From the occurrence of Zánskár rocks on the southern border of these rocks, it has already been inferred that the rocks on that border are inverted, and from the correspondence of the strata on the two sides of the gneissic band, it would seem that the inversion extends as far as the middle of that band, which really forms a crushed anticlinal. For the convenience of reference the rocks of this section may be tabulated as follows, arranged in their proper serial position.

Zánskár system ..	1.	Blue limestones, quartzites, and carbonaceous shales.
Panjál system	2.	Greenish slates and sandstones with amygdaloidal traps.
	3.	Black and green slates with thick beds of conglomerate, containing pebbles of quartzite and slate.
	4.	Whitish quartzites and sandstones.
	5.	Black schisty slates with pebbles of gneiss and quartzite.
	6.	Imperfectly granitoid gneiss, with occasional bands of schists and quartzite.

The resemblance of some of the rocks of No. 3 to the lower division of the Blaini series, both petrologically and stratigraphically, cannot fail to be noticed, and will be further alluded to below. The whole section is several thousand feet in thickness, though no nearer estimate has yet been attempted.

The last section across the Pír-Panjál range is taken more to the south-east, and follows the Jamu and Káshmír road across the Banihál pass: it is represented diagrammatically in figure 1, of plate III. To the southward of the pass, in the Chínáb valley, on the banks of the tributary Chanj stream, the limestones and shales of the Zánskár system are not exposed, and the first rocks seen within the Sirmúr boundary consist of black and rusty-brown slates, generally splitting into irregular flaggy masses, and containing numerous beds of sandstone and quartzite. These rocks have the usual north-easterly dip and continue for a mile-and-a-half up the Bichlári stream, where they are conformably succeeded by a fine-grained gneiss, at first foliated, but further in of a more granitoid and sometimes porphyritic structure. This gneiss has at first a north-easterly dip of about 60°, but becomes quite vertical in the middle of the zone, and beyond this resumes its north-easterly dip. On both its boundaries this gneiss passes into semi-crystalline rocks, and these again into the unaltered slates, so that it is almost impossible to draw any accurate boundaries on the map. The gneiss is succeeded

by the slate and sandstone series, having at first a north-easterly dip, and leading on to a well-marked anticlinal and synclinal axis. An occasional band of blue earthy limestone, or carbonaceous shale, occurs among these slates, and on the pass itself there are beds of white and pinkish cherty grits, and a very few of the volcanic rocks, so abundant in the Pír-Panjál section. The relations of these rocks to the Zánskár rocks on the northern side of the pass have been already discussed in a previous chapter. This section, like that of the Pír-Panjál pass, seems to indicate that the strata on the southern side of the gneissic core are inverted. The almost entire absence of trappean rocks in this section is a very noteworthy point.

To the north-west of Báramúla the above-mentioned amygdaloidal and slaty rocks may be traced round the whole of the north-western extremity of the Káshmír valley, underlying the Zánskár rocks of Trigamma, and thence along the north-eastern side of the valley, where they may be more fully noticed.

Underlying the Zánskár rocks in the neighbourhood of Sirínagar and Mánas-Bal, the amygdaloidal rocks of the Pír-Panjál attain a great development, and, as already stated, in some instances entirely obliterate the characteristic rocks of the Kuling series. These rocks form almost the whole of the small isolated hill on which the fort of Hari-Parbat near Sirínagar is built, and also the conspicuous hill at the back of the town so well known to all visitors as the Takht-í-Suleimán.[1] On the north-eastern side of the latter, on the road from the Múnshi-Bágh to the Dal lake, fine splintery black and green slates are partly interstratified with the amygdaloidal rocks, but in great part appear to underlie them. These slates form a consider-

1 Meaning the "Throne of Solomon"—a name commonly applied in northern India to isolated hills, generally crowned with a temple.

able part of the higher hills to the north-east of the gap behind the Takht through which the road passes, while on the north-eastern side of the Dal lake the high ridge forming the outer boundary of the Arrah valley, consists mainly of the massive amygdaloidal rocks. At the foot of this ridge, near the Nishat-Bágh, there occur some calcareous sandstones, dark cherts and slates, occasionally containing obscure impressions of fossils, and dipping towards the ridge, which may be the representatives of the Kuling series, though they are not so coloured on the map. The amygdaloidal traps of the above-mentioned ridge are continuous with those at the mouth of the Sind valley, Mánas-Bal, and the shores of the Walar lake.

The amygdaloidal and allied rocks in this neighbourhood are generally of a greenish, or blackish, colour, sometimes containing numerous amygdules; but at other times are homogeneous, fine-grained, rocks like green-stone. The latter rock not unfrequently contains large isolated pear-shaped amygdules of chalcedony, reaching to two or three inches in length. The whole formation is generally devoid of any visible signs of stratification, and forms bold, massive cliffs, from which cuboidal fragments disintegrate. In many parts of the Pír-Panjál, and, as already mentioned, in the neighbourhood of Awántípúr, these rocks pass insensibly downwards into the argillaceous and arenaceous rocks with which they are interstratified.

A microscopical examination of three specimens of these rocks has been made by Colonel Mc'Mahon. The first of these specimens is described as a finely porphyritic rock, which appears to be undoubtedly a true lava, or trap, partly altered by subsequent metamorphism. Crystals of white felspar, with their axes turned in all directions, in a manner very characteristic of trap, are of common

occurrence in this rock. On heating, the rock gives off aqueous and acid vapours, far below a red heat, indicating that aqueous action has played a part in its metamorphism. The probable presence of iron sulphide is also indicated. Another evidence of the metamorphism which has taken place subsequently to the solidification of the rock is afforded by the presence of flocculent chloritic matter within the crystals of felspar, which in all probability were originally transparent triclinic prisms. This cloudiness has nearly obliterated all traces of the twin triclinic crystals, although remnants of them are probably indicated by the parallel bands of colour which still appear in some of the crystals under the polariscope. This rock readily fuses into a bead, and contains 54·1 *per cent.* of silica. The second specimen is a compact rock apparently consisting of an iron-silicate disseminated in thick flocculent masses through a felspathic base; it shows no traces of crystalline structure, and may be either a trap, or an altered slate. The whole of the colouring matter of the iron-silicate is extracted by hydrochloric acid, whence it would seem that this mineral is not hornblende. The rock readily gives off aqueous vapour when heated, and contains 62·9 *per cent.* of silica, 30 *per cent.* of alumina and iron, as well as lime and a small proportion of magnesia. As far as its chemical composition goes there is, therefore, no reason why the rock should not be a trap, but it is not impossible that it may be a sub-aqueous volcanic product, such as ashes deposited in the form of mud on a sea-bottom, the product of the sub-aërial denudation of trap. The third specimen is an amygdaloidal rock, in which the above-mentioned quaquaversal arrangement of felspar crystals is well displayed, from which it is inferred to be a trap. This rock likewise shows signs of metamorphism after its consolidation, as patches of chlorite occur in many of the felspar crystals. It is considered probable that it was originally a porous, or

scoriaceous lava, and has been subsequently altered by the infiltration of foreign matter through its pores.

As the result of a later examination of specimens from Mánas-Bal, Colonel Mc'Mahon writes:—"I do not doubt their being true traps, *i. e.*, volcanic rocks; but I do not think anything would be gained by attempting to describe them. . . . . . The specimens are intensely altered through the invasion of water; all the pyroxene being removed and epidote substituted for it. The determination of the species would be to a large extent guess work."

When noticing similar rocks in the Dalhousie district, the same able observer remarks[1] that he is quite satisfied "that they are more or less altered lavas"; while in some further notes regarding these rocks obligingly given to the present writer, Colonel Mc'Mahon observes that the final result of the microscopical examination of all the specimens affords abundant evidence that they are lavas erupted at the surface of the earth's crust. No existing volcano could yield a more typical lava than one of the specimens. "The alteration exhibited by these rocks appears to have been the result of either the slow percolation of water, or of hydro-thermal agencies. This alteration is not a mere local peculiarity, but appears to prevail throughout these rocks, and to extend over a large area.

"The result of their examination under the microscope is, therefore, to support the conclusion (as to their age) arrived at on other grounds in my paper on the geology of Dalhousie."

In the amygdaloidal varieties, the amygdules range in size from a pin's-head to two or three inches in length: when of a large size the amygdules are frequently pyriform. There are four chief varieties of

1 "Records," Vol. XV., p. 35.

these amygdules, some being entirely red or white, while others have white centres and green borders, and others again red centres with green borders. The two first mentioned varieties are the most common. Occasionally the matrix is nearly purple in colour with greenish amygdules. A very characteristic rock of not unfrequent occurrence among the traps of the Káshmír valley, is a dark compact trap, having at intervals clusters of small white (? felspar) crystals diverging from a central point in the form of a many-rayed star, to which Dr. Verchère applied the name of suleimanite, from its common occurrence in the Takht-í-Suleimán.[1] One of the most common varieties may be described as a felspar-porphyry, or perhaps rather as a porphyritic trap, since the base appears to be basaltic; and accordingly these rocks may generally be alluded to as altered basalts.

From the foregoing observations it may be taken as certain that the amygdaloidal rocks of Káshmír are of volcanic[2] origin, and that they are mingled with what are probably trap-ashes and other rocks, which from their mode of deposition and from the effects of subsequent metamorphic action, have become so fused with detrital sedimentary rocks, that it is now frequently impossible to distinguish the one from the other. With regard to their geological age and mode of origin, it will in the first place be apparent from the descriptions given in an earlier chapter, that these rocks cannot be intrusive, since they underlie the rocks of the Zánskár system without penetrating them by dykes: and as they are interstratified with those rocks, and also with the slates of the Panjál system, it is evident that they must be of

1 "Jour. Asiat. Soc. Bengal," vol. XXXV., pt. 2, p. 120. The name was originally spelt soolimanite, but has been altered to the requirements of the modern spelling of Indian names.

2 The term volcanic is employed here as analagous to igneous, and does not necessarily imply any connection with a true volcano.

contemporaneous origin with the rocks with which they are associated. This conclusion, as Colonel Mc'Mahon observes, is confirmed by the non-local character of the alteration to which they have been subjected. As has been already partially noticed, they are extremely variable in distribution, being sometimes found underlying the Zánskár rocks in great thickness, and a short distance away totally unrepresented. As they in general immediately underlie the Kuling division of the Zánskár system, which corresponds to the lower carboniferous, and as that series is underlain in Spiti by rocks probably corresponding to the upper Silurian (Múth series), it is probable that the Káshmír traps also correspond in the main to that period in the sense in which it is employed here. From the fact, however, of their being sometimes interstratified with, and obliterating the characteristic beds of the Kuling series, it seems probable that they partly correspond in time to those rocks. It is, however, as before said, more convenient for the purposes of geological description to include the whole of the traps together as forming, in this district, the higher part of the Panjál system, which may, at all events in great part, be considered as the representative of the silurian system.

No traces of any ancient volcanoes, or of 'necks,' or dykes, have hitherto been detected in the Panjál system, and the mode of emission of their volcanic rocks cannot, therefore, be determined. From the large area of country over which they may be traced, it might at first appear probable that these rocks belong to the type of "fissure (massive) eruptions" of Professor A. Geikie.[1] The existence of what are apparently volcanic ashes, and of originally scoriaceous lavas, seems, however, to be an objection against this view, and to be in favour of the origin of these rocks from true volcanoes. This view

1 See "Text-Book of Geology," 1882, p. 257.

is supported by the apparently sudden thinning-out and disappearance of the traps in many localities, which is indicative rather of numerous separate lava-streams, than of one continuous sheet of lava. To decide definitely the mode of emission of these rocks, it will be necessary that the channels through which they have traversed the underlying rocks should be discovered, as there is no likelihood of volcanic cones, if such existed, having escaped subsequent denudation.

From the extremely intimate connection existing between the traps of the valley of Káshmír and the rocks of the Kuling series, which are certainly of submarine origin, there would seem to be little or no doubt that the traps were likewise poured forth beneath the surface of the ocean. In regard to submarine lavas it is remarked by Professor Geikie[1] that these rocks differ from lavas poured forth on land only "in their more distinct and originally less inclined bedding, and in their tendency to the admixture of non-volcanic or ordinary mechanical sediment with the volcanic dust and stones. No appreciable difference either in external aspect or in internal structure seems yet to have been established between subaërial and submarine lavas. Some undoubtedly submarine lavas are highly scoriaceous. There is no reason, indeed, why slaggy lava and loose, non-buoyant scoriæ should not accumulate under the pressure of a deep column of the ocean." In their great intermixture with what are apparently materials of non-volcanic origin, the traps of Káshmír agree well with the above-mentioned characteristics of submarine volcanic rocks.

In their mode of occurrence these partially altered volcanic rocks of Káshmír appear to present considerable resemblances to certain still more altered amygdaloidal and tufaceous volcanic rocks occurring

1 *op. cit.*, p. 254.

in the devonian of Devonshire, beneath the carboniferous.[1] The metamorphism of the latter has, however, been so great as to produce a schistose structure in the amygdaloids, which is wanting in those of Káshmír. In Devonshire rocks which are partly true lavas, partly tuffs, and partly tufaceous sediments, are mingled together in a manner very similar to the mode of occurrence of the palæozoic volcanic rocks of Káshmír.

Summing up the general conclusions to be derived from the study of these rocks,[2] it appears probable that during the Panjál period, which immediately preceded that of the lower carboniferous, very extensive submarine eruptions of lava and ashes were emitted, probably from volcanoes: these eruptions probably took their origin from several distinct points, and at several distinct intervals of time. Throughout the whole period, during which these eruptions were continued, uninterrupted deposition of ordinary sedimentary detrital material appears to have continued at the sea-bottom, the strata resulting from which became at once so intimately mingled with the volcanic products as to render it now difficult to distinguish between the original factors of the deposit; while subsequent metamorphic action has served to obliterate still more completely their original distinction. In certain spots, as at Mánas-Bal, in the Káshmír valley, the eruption of volcanic matter appears to have continued during a part, or the whole, of the Kuling, or lower carboniferous, period, and to have rendered the distinctive sedimentary rocks of that period in many places totally unrecognizeable.

Having now established the volcanic nature of the amygdaloidal

1 Rutley, 'Quar. Jour. Geol. Soc.,' vol. XXXVI., p. 285, *et seq.*

2 Other places where these rocks occur are described below, but it is more convenient to introduce this summary here, instead of later on.

rocks, the consideration of the general characters of the Panjál rocks in the valley of Káshmír and its neighbourhood may be resumed. In the trans-Jhelam continuation of the Panjál range, known as the Káj-nág, a central core of granitoid rock is found in the immediate neighbourhood of the Jhelam, but beyond this point all the rocks, with the exception of some small patches of the Zánskár system, belong to the Panjál system. These rocks continue into the lower Kishanganga valley and Khágán, where they gradually pass into metamorphic schists, which will be treated of in a later chapter. Higher up the Kishanganga valley, near Kairen, the northern boundary of the non-metamorphic Panjál rocks crosses the river, and runs for some miles at a considerable distance south of the river: higher up, in the Fulmai district, this boundary again crosses the river and thence sweeps round to the north of the Zánskár rocks of Tilel and Drás. In this extensive area the petrological characters of the strata, though presenting the same general features, yet present a considerable amount of local variation. On the north-eastern flanks of the Káj-nág range, in what are apparently the higher beds, the amygdaloidal traps are very strongly developed. In the lower Kishanganga valley, however, shales and slates occur immediately below the lower Zánskár rocks, as is shown in the following section taken in the neighbourhood of the Tútmári pass, leading from the north-western end of the Káshmír valley into the Kishanganga valley[1] :—

Zánskár system.	1. Blue limestones, and thin crumbly carbonaceous shales.
Panjál system.	2. Dark shales, slates, and sandstones. 3. Quartzites, sometimes with gneissic structure slates, and thin beds of conglomerates and amygdaloidal lavas.
Crystalline and metamorphic system.	4. Porphyritic granitoid gneiss.

[1] The name of this pass is not given on the map; it is merely marked 'pass,' at the head of the Karna tributary of the Kishanganga.

From this section it appears that the volcanic rocks in this district occur mostly on a horizon considerably below that of the Kuling series, in place of just below it: similar beds exist in the Panjál range at corresponding horizons, indicating more than one eruption of these rocks.

The general characters of the Panjál rocks on the north-eastern side of the Káshmír valley will be best gathered from the description of several sections. As already mentioned, the volcanic rocks are the most frequent along the skirt of the mountains on this side of the valley, where they are generally in close proximity to the rocks of the Zánskár system. In the Lidar valley (see figure 2 of plate III.), below the Zánskár rocks of Pailgám, there is a great mass of amygdaloidal and other volcanic rocks, showing some signs of stratification in their upper beds, but of an extremely massive character inferiorly: they extend to the south-east into the Wardwan valley. Lower down that valley these rocks are apparently underlain, as mentioned in a previous chapter, by several repetitions of the Zánskár rocks, with the characteristic Kulings, infolded with the non-volcanic representatives of the Panjál system. Still lower down the valley the traps are again found directly underlying the lower Zánskár rocks.

In this section, as has been already mentioned, the occurrence of several distinct outcrops of the lower Zánskár rocks overlying one another in what is apparently a normal sequence, clearly proves that the rocks on this line have originally been thrown into a series of folds of varying latitude, which have been mainly inverted on the southern side, and subsequently enormously denuded. It has been attempted to reproduce the original extent of these beds in the figured section. In this section a very remarkable feature is that the rocks of the Kuling series are underlain in different parts of the

valley by rocks of totally different petrological characters, or, in other words, at one point by volcanic rocks, and at another by slates and quartzites. The only explanation of this feature appears to be either the occurrence of numerous faults, or that the lava-flows were originally limited, and by the probable tendency of sharp flexures to take place at the junction of the dense rocks forming one side of such flows, with the softer sedimentary rocks of the same period. With respect to the first hypothesis it may be observed that both in this section, and in the analagous one in the upper Sind valley (plate III., figure 4), there is no sign of the existence of any fault. In the latter section, moreover, there is a complete passage from the sedimentary Panjáls of Gagangír into the overlying lower Zanskárs, and another from the traps of the Shalián range (indicated by crosses) into the same rocks. Again, there is a similar passage from the lower Zánskár rocks, south-west of the Zoji-lá, into the sedimentary Panjáls of the pass. It is, therefore, very difficult to see how the fault hypothesis can explain the section, and it seems necessary, in this and similar sections, to accept the second hypothesis.

The undoubted occurrence (on either of the above hypotheses) of a large series of flexures, generally inverted on their southern side, in the rocks of the Lidar valley lends confirmation, if indeed any be required, to the view expressed above as to the inversion of the rocks on the southern side of the Pír-Panjál range, since it is highly probable that the lateral thrust which folded the strata of the former area would have also affected in the same manner those of the latter area. It is important to observe that in the Lidar and Sind valley sections there are no strong conglomerates immediately underlying either the traps or the Zánskár rocks.

The existence of a nearly similar feature along the whole of the

southern border of the Zánskár rocks of the northern division of the Káshmír basin has been already indicated in the description of those rocks, and in the Sind valley has been more fully noticed in the preceding paragraphs. Between the two bands of the Kuling rocks along this line, there occurs a continuous ridge of dense volcanic rocks, which is presumed to contain a concealed and compressed anticlinal axis (plate III., fig. 4), and whose very density may have been the inducing cause of this repetition of the Kuling series.

In the Wardwan valley beneath the southern band of Kuling rocks there occurs a great thickness of slates, sandstones, quartzites, and conglomerates, with a few intercalated bands of volcanic rocks, continuing till some distance below Inshin, where they will be again noticed below. The general appearance of the scenery presented by these rocks is shown in the woodcut on the opposite page (fig. 9), from a sketch by Mrs. Bridges.

In the upper Lidar valley, to the north-east of the Zánskár rocks of Pailgám, the Panjál rocks, which, as already said, appear to underlie the former, consist mainly of a blueish-green slaty-sandy rock, which, though not a true lava, is probably in part of volcanic origin, and has obliterated the characteristic rocks of the Kuling zone. Similar, or more truly slaty rocks, with a few beds of amygdaloids continue to the border of the main area of Zánskár rocks.

A section taken across the hills from Pailgám into the Sind valley, shows that to the westward of the Zánskár rocks at Aro, Panjáls continue the whole way to the Sind valley: the latter consist of chloritic sandstones, and grey and black slates, with occasional bands of amygdaloidal trap. The dip is generally south-westerly as far as Gwáshbrári, beyond which it is north-easterly. In the Sind valley the Shalián ridge of amygdaloidal trap below Sonámarg, has

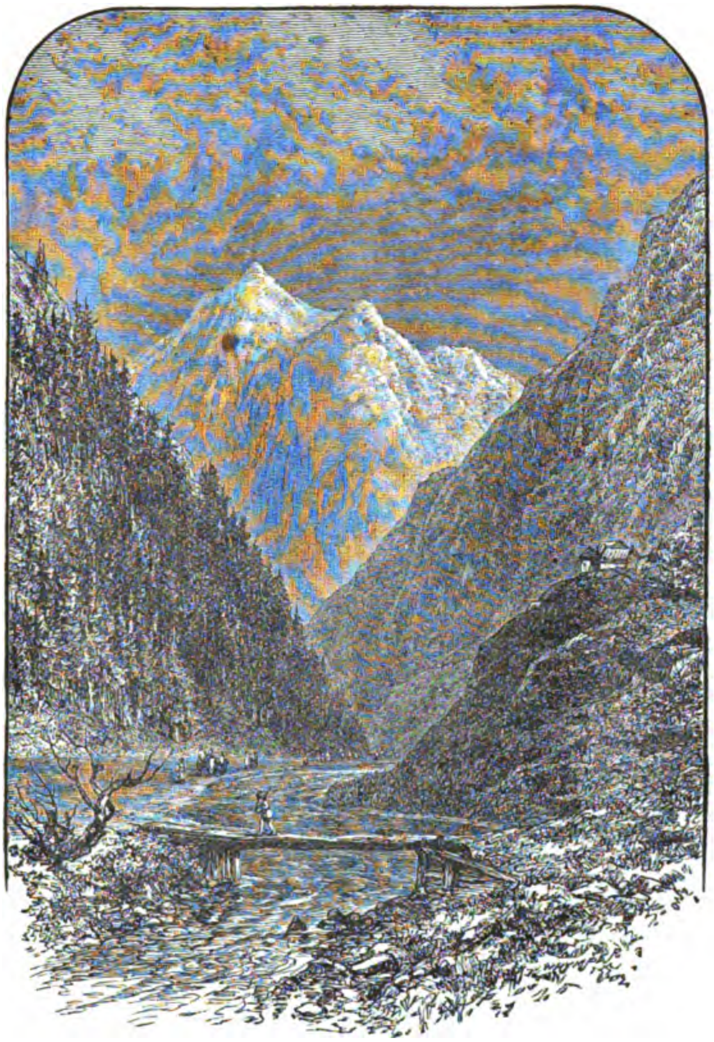


FIG. 9.—The Wardwan valley near Inshin.

been already described in the previous chapter. To the south of the Kuling band at Gagangír the Panjáls have a regular north-easterly dip, and consist of dark-coloured slates and sandstones, with local bands of amygdaloids, and of the characteristic conglomerate of the Pír-Panjál range. On the right bank of the Sind river these rocks have a north-easterly dip, but on the left bank an anticlinal axis occurs near the village of Hari. Lower down the valley, at the village of Kangan, and on either side of the mouth of the tributary Wangat valley, the rocks at the base of the cliffs consist of a considerable thickness of coarse gneiss, mingled with grey sandstones, and beds of limestone, some of which is white and highly crystalline, and some blue and scarcely altered. On the right bank of the river these rocks have a north-easterly dip, and appear to underlie the slates and amygdaloids which are in force in the Wangat valley: on the left bank the relations of the rocks are concealed by forest. To the south of these gneissic rocks, the rocks at the mouth of the Sind valley consist mainly of the massive amygdaloidal traps, which have been shown to immediately underlie the Zánskár rocks. The age of the Kangan gneiss is not easy of determination: if the sequence be uninterrupted, from its relation to the traps, it would appear to occupy a place high in the Panjál system, but no such rocks are found in a similar position in the neighbourhood, and it may, therefore, be that the junction of the rocks is not really undisturbed, and that the gneiss may be below the great mass of the Panjáls, as in the Panjál range itself.

The notice of the Panjál rocks of the north-eastern side of the Káshmír basin may be concluded by describing the section on the Káshmír and Gilgit road, from Bandipúr to the south of the Dorikun pass, and also the rocks met with between this road, north of Gurez

and Drás, to the eastward of which the Panjál rocks may be considered as belonging to the Zánskár basin.

At Bandipúr, to the westward of the Zánskár limestones, the rocks consist chiefly of amygdaloidal traps, and slates, traversed near that village by a well-marked anticlinal axis. As far as the little camping-ground of Trágbal, situated on the summit of one of the spurs of the main ridge, the dip is generally low and northerly; and the amygdaloids gradually diminish in frequency as that place is approached; green, black, or brown, sandstones and slates becoming the prevailing rocks. Above Trágbal the rocks consist almost entirely of black slates, preserving the same dip, till a synclinal axis is crossed a little to the south of the Rájdiángan pass, followed shortly by an anticlinal. Descending from the pass towards the Kishanganga, after a few miles a band of gneissic rocks with a northerly dip, and apparently overlying the slates and sandstones, is met with. Beyond this gneiss black slates, with the same dip, occur in force, while towards Kunzalwán, as the Zánskár rocks of Gurez are approached, bands of amygdaloids become not unfrequent in the series. The rocks immediately underlying the Zánskár system are mainly blueish-green slaty sandstones, passing imperceptibly into the Kuling series, and as in other districts, probably consisting of a *melange* of volcanic and detrital materials. The gneissic band, which forms an elongated ellipsoid, probably indicates a concealed anticlinal flexure, which dies out to the north-west and is replaced by a synclinal of Zánskár rocks, following the usual Himalayan rule of the association of a double system of flexures, one of which is parallel to the strike of the rocks, and the other at right angles to the same. To the north of the Zánskár rocks of Gurez, slates, sandstones, amygdaloids, rib-band-jaspers, and massive-conglomerates, with here and there a thin

calcareous band, all belonging to the Panjál system, continue to the mouth of the Nagai stream, where they have a south-westerly dip, and pass gradually downwards into a dark schistose gneiss, apparently the same as the band south of Gurez, and forming the commencement of the great crystalline area of Baltistán. At the junction with the Kuling rocks of the Burzil river, the Panjál rocks have a north-easterly dip, and apparently overlie the former; they must, however, really be inverted. Many of these rocks have their 'joint' surfaces covered with a thin coating of a serpentinous mineral. The conglomerates, which are often twenty or thirty feet in thickness, besides fragments of slate and other rocks similar to those of the Panjál system, contain numerous pebbles of granitoid gneiss and other metamorphic rocks: similar pebbles occur in the Panjál conglomerate near Gúrez.[1]

Between the Burzil river and Drás, a wedge-shaped mass of Panjál rocks occurs between the crystallines of Baltistán and the Zánskár rocks of Tilel. Near the village of Badagám, in the latter district, volcanic rocks are strongly developed, and judging from the boulders in many of the tributary streams flowing from the north, these rocks seem to prevail on the northern watershed of the Kishanganga. On the right bank of the Kila-Shai stream very fine-grained black slates form the summit of the ridge, some of which bear faint impressions which may possibly have been caused by graptolites. In the eastern end of Tilel and thence to Drás, a light-coloured and very hard ribband-jasper, as well as numerous beds of conglomerate, are very marked features of the Panjál rocks. Near the town of Drás itself these rocks generally have an extremely massive character, showing very indistinct signs of stratification. The prevailing rock is usually

1 It is remarkable that some of the conglomerates contain pebbles of a limestone exceedingly like the limestones of the supra-Kuling series.

dark green in colour and is described by Dr. Stoliczka[1] as being "generally quite massive, like greenstone; only occasionally it is thinly bedded with bacillary structure. To all appearance they are the same rocks as about Srinagar. . . . . . . The green rocks decompose very readily, and weather out reddish, as greenstones often do." These rocks acquire a deep black glaze both by the action of water, and of the sand-blast. There is no doubt that they correspond to the traps of Sirínagar, although the amygdaloids are less well developed: they may very possibly owe their origin more extensively to scoriaceous matter, mingled with ordinary detrital sediment, true lava being present to a smaller extent. The relations of these rocks to the Zánskár rocks to the south, and the possible existence among them of representatives of the tertiary rocks of the Indus valley, have been already noticed in a previous chapter. Their south-easterly extension and connection with the Panjál rocks of Baltistán will be brought to notice in the sequel.

The Panjál rocks of the Zoji pass, occurring in the middle of the area of Zánskár rocks, have already been sufficiently noticed in an earlier chapter,[2] and it accordingly only remains to notice the Panjál rocks in the neighbourhood of the middle part of the Wardwan valley to complete the notice of these rocks in the Káshmír basin. Taking up the Panjál rocks of the valley of Káshmír at Naubúg they are seen to form an apparently ascending series, interrupted by several minor flexures, from this place to the summit of the Margan pass: from their relations to the Zánskár rocks of Naubúg it is, however, quite probable that a concealed anticlinal exists somewhere between these two points. For some distance

1 "Scientific Results of Second Yarkand Mission.—Geology," p. 12.

2 See page 146.

above Naubúg amygdaloids are the prevailing rocks, probably indicating the presence of beds high in the series, while nearer the pass slates and quartzitic sandstones are the common rocks: the slates are sometimes banded, but are more usually of a uniform olive-green colour marked with small ferruginous spots: at the top of the pass the rocks are mainly whitish quartzitic sandstones. Occasional beds of conglomerate and amygdaloid occur throughout the series. A short distance on the eastern side of the pass there is a well-marked synclinal axis, the rocks beyond this forming a descending series into the Wardwan valley. The quartzitic sandstones on and near the pass exhibit very beautiful examples of ripple mark: this is well displayed on a large white slab which has been set up as a 'cairn' on the top of the pass itself. These whitish quartzitic sandstones, which are probably at the top of the Panjál system, the volcanic rocks being absent, present a striking similarity to the topmost beds of the Múth series, and to some of the upper Blaini rocks, and they may very probably be considered as their equivalents. In the Wardwan valley where the Panjál rocks have been already noticed as far as Inshin, the river at and near that place follows on the line of an anticlinal axis. This axis leaves the river some distance below Inshin, and the latter then flows for some distance through strata with an easterly dip, below which after crossing a synclinal axis the opposite dip prevails. To the south of this the rocks which at first consisted of bluish slates and sandstones, gradually become more and more micaceous and metamorphosed, until they are underlain by an anticlinal core of true gneiss, some seven miles above the village of Maru, or Petgám. Several folds of alternating strata of slates and gneiss are met with for some distance below the latter place, until the gneiss becomes the predominant rock of the district. The Panjál rocks continue to the westward of the river till they again cross it

near the village of Ekali: at this point the junction between the Panjál rocks and the gneiss is apparently on a faulted anticlinal axis; the rocks on the southern side consisting of black slates, which continue from this point to Kishtwár, and unite with those of the south-western extremity of the Káshmír valley, and the Pír-Panjál range. A minor anticlinal axis to the north-west of Kishtwár exposes a core of dark schistose gneiss. The south-western extension of these rocks will be noticed below.

Viewing the rocks of the Káshmír basin and the Panjál range as a whole, it seems that they are surrounded to the north-west, north, and north-east by crystalline rocks (comprehending both some altered equivalents of the Panjáls and a primitive gneiss), and to the south-east send off an arm on either side of the crystallines of the Zánskár range uniting with the rocks of other basins. The Pír-Panjál range itself forms an anticlinal axis exposing here and there disconnected portions of a central crystalline core which separates the newer rocks of the Káshmír basin from those of the Outer Hills. Another imperfect anticlinal axis is probably indicated by the gneiss to the north-east of the Walar lake, which tends to separate the newer rocks of the north-western end of Káshmír from those of Gurez. To the south-east where this axis has died out, the newer rocks of the two areas are connected by intervening patches. The Zánskár rocks of the Outer Hills, of the Káshmír valley, and of Gurez and Tilel, indicate the three chief synclinal axes of the whole area.

The Chamba basin and the Dalhousie district.

In the foregoing paragraphs the Panjál rocks of the Káshmír valley and of the Pír-Panjál range have been traced as far as Kishtwár, and their south-easterly extension may now be considered in the area which it has been agreed to call the Chamba basin, com-

prehending the districts to the south-east of Kishtwár. The north-eastern border of this area is a well defined one, formed by the gneiss of the Zánskár range. At the southern end of the basin its outer boundary is formed by the crystallines of the Dhauladhár, which are probably continuous with the corresponding rocks of the Panjál range. It will, however, be convenient to treat of the Panjál rocks of the Chamba basin proper, and of the districts adjoining the Outer Hills under one heading, adopting the same course as was followed in the case of the Káshmír basin and the Pír-Panjál range.

At Kishtwár the Panjál rocks mainly consist of black flaggy slates, with a tendency to a micaceous structure: an anticlinal axis, with a north-westerly direction, traverses these rocks a little to the north of the town. In the sharp bend which the Chínáb makes immediately above the town, the river cuts directly across the strike of the rocks; above this bend, however, the course of the river is approximately coincident with that of the strike. In proceeding up the river from Kishtwár the above-mentioned anticlinal is first crossed, after which a synclinal axis is met with. Still higher up the river the rocks gradually assume a metamorphic structure, till at the village of Piyás they consist of quartzitic and micaceous schists gradually passing inferiorly into true foliated gneiss, which in its turn is underlain by granitoid rocks. Near Piyás many of the tilted beds of Panjál rocks may be observed consisting at one end of little altered slate, and a few yards distant converted into a quartz or mica-schist. From this point the slaty rocks leave the river, but are continued at some distance to the south, the river passing through more or less metamorphosed strata till a little eastward of the British forest-officer's station of Kilár, in Chamba territory. At the latter place the rocks have a southerly

dip, and consist of various schists overlain immediately to the south of the village by a very thick band of granitoid gneiss. The latter is again conformably overlain by blueish slates and sandstones, which here succeed the single bed of granitoid gneiss somewhat suddenly, although micaceous schists occur below the latter: the slaty rocks are probably the same as those of Kishtwár.

From the Chínáb near Kilár a section has been carried by Colonel Mc'Mahon across the Sachi (Sach) pass to Dalhousie,[1] and it will be simplest to consider first this section, and then the Panjál rocks on the outer side of the Dhauladhár range, after which the description of the corresponding rocks of the Chínáb valley may be resumed. On the southern side of the Chínáb, opposite Kilár the gneiss is described as foliated and not granitoid, and as conformably overlain by mica-schists, with a south-westerly dip; bands of the one at first interstratifying with those of the other, and the passage between the two being somewhat gradual. There are innumerable intrusive dykes of white oligoclase granite in the gneiss, near its junction with the schists, passing up some distance into the latter. The micaceous schists are overlain by silicious and quartz schists, often fissile, but never passing into true slates. Upon these rocks is a band of a sub-crystalline, perhaps magnesian, limestone, considered to be possibly the equivalent of the Blaini limestones of the Simla area, but which may be the representative of the lower Zánskár system: this is again overlain by schistose (or slaty) beds, succeeded by decidedly conglomeritic rocks at the top of the Sachi pass. A synclinal axis occurs a little to the north of the pass, followed by an anticlinal coinciding with the very summit of the pass, the beds on the southern side having a south-westerly dip. The conglomerates continue a short distance to

1 "Records," Vol. XIV., p. 305, *et. seq.*

the south of the pass and are followed by fine-grained quartz schists, mica-schists and slaty mica-schists, occasionally passing into micaceous slates, with the same general south-westerly dip, till near the village of Sai, where they are succeeded by the conglomerates of the Sachi pass. A synclinal fold occurs in the middle of these conglomerates, and to the southward they are in direct contact with, and apparently underlain by, the limestones and other rocks of the Zánskár system, described in a previous chapter. The conglomerate is described as having a matrix of "a slaty schistose rock, at times even foliated. It contains pebbles of white quartz of all shapes and of various sizes up to 9 inches in diameter. Some are well rounded and present sections of the size and shape of an egg; others are sub-angular to angular. The white quartz pebbles are the most abundant, but the rock also contains grey and blue quartzite, and quartzitic sandstone pebbles, sub-angular to rounded, which weather various colours."

Colonel Mc'Mahon then observes, "I have no hesitation in correlating this with the Blaini conglomerate of the Simla area. As in the typical Blaini rock, occasionally white quartz veins meander about in an irregular manner, and a person not familiar with the rock might suppose that the "eggs" were sections, or fragments of such veins, but a careful study would show him that it is a true conglomerate. As in the Simla area, so here, some of the blue quartzite pebbles contain thin white quartz veins that do not pass into the matrix, showing that the pebbles were metamorphosed, and were ground down into their present shape, before they found their resting-place. The pebbles in some beds are very sparse, in others very abundant.

"The conglomerate differs from that of the Simla area in having

expanded to a great thickness. A synclinal flexure, however, takes place in the centre of these beds, and it is possible that they may also be repeated by other flexures, the evidence of which has been obliterated, or by slates of a slightly lower horizon having been folded up with them. In any case, their real thickness must very greatly exceed that of corresponding beds in the Simla area. Dr. Stoliczka estimated the thickness of the Múth conglomerate of Spiti,[1] which he correlated with the Blaini conglomerate,[2] at from 500 to 600 feet.

"At the junction of the conglomerate with the limestone series, the latter has suffered considerable contortion, and a bed of conglomerate has been from this cause folded up with the limestones."

On the north-western side of the Rávi, to the north of the village of Duire, a band of trap similar to that of the valley of Káshmír is intercalated between the conglomerates and the Zánskár rocks, but disappears before reaching the Rávi. This trap shows no signs of having altered the limestones: it is described as consisting in part of an intensely hard felspar porphyry, probably similar to some of the Káshmír varieties. Colonel Mc'Mahon is in doubt whether the disappearance of the trap towards the valley of the Rávi is due to dying out, or to faulting. As already observed, in the opinion of the present writer the former view appears the more probable.

It is inferred from this section that on the north-eastern border of the Zánskár zone the conglomerates and the traps, together with some of the slates to the north, must be inverted on the former, which, as previously observed, must form a compressed synclinal axis. "A similar inference arises in the case of the beds on the north

1 "Memoirs," Vol. V., p. 22.

2 *Ibid.* p. 141.

side of the pass for, whether the limestone which crops out there represent upper silurian (Blaini), carboniferous, or triassic [Zánskár] limestones, its proper place is above the conglomerate, and consequently the rocks here must also be inverted."

On their southern border the Zánskár rocks are underlain by the Blaini conglomerate, which, however, is not so thickly developed as on the northern border; the outcrop of this conglomerate has been traced for a considerable distance to the north-west and preserves an approximately parallel course to the trans-Rávi continuation of the Dhauladhár crystallines; it runs near Manjere, Digi, Baundal, and the Padri pass. The conglomerate is in turn underlain by slates, indistinguishable from the infra-Blaini series, or "Simla slates" of the Simla district, and accordingly considered to be probably the same. The slates pass gradually downwards into micaceous and quartzose schists, conformably overlying, and apparently passing downwards into the crystallines of the Dhauladhár range. To the northward of the Rávi the slates are described as continuing downwards to the granitoid crystallines; the former being indurated, and sometimes silicious and massive.[1] A very similar junction is described on the northern side of the range at Maila, south of Chamba.[2] Occasionally near the junction of the two rocks, the slates are contorted, and there is a sudden reversal of dip, with some local dislocation; but at the actual junction the dip of the slates is always in the same direction as that of the gneiss. To the south of the Padri pass, near the village of Langera, Colonel Mc'Mahon observed a boulder of granitoid gneiss in the conglomerates, 1 foot 3 inches in length.

1 "Records," Vol. XVI., p. 36.

2 *Ibid*, p. 38. The gneiss above Maila should be represented on the map accompanying the present memoir as crossing to the north side of the Rávi.

There can be no question that the beds between the Zánskár rocks of Chamba and the crystallines of the Dhauladhár range correspond to the Panjál rocks of the Káshmír valley, and they form a very important link in connecting the latter with the palæozoic rocks of the Simla area. It cannot, however, be taken as certain that all the conglomerates of the Káshmír valley correspond to the Blaini conglomerate, since in the Pír-Panjál range the conglomerates appear to occur in the middle of the slate series, and are never, even when the traps are absent, in direct contact with the Zánskár rocks. The Blaini series in the Pír-Panjál must, therefore, in all probability be at least partly represented by slates, and it is at present impossible to determine in that range the precise equivalents of the "Simla slates." Of the slaty and schistose rocks of Chamba Colonel Mc'Mahon remarks, that "we have now seen that at both ends of our section micaceous and quartzose schists, metamorphosed into perfect mica-schists in many instances, rest conformably upon gneiss. . . . . . The schists I take to be lower silurians. On these rest slates which I correlate with the "Simla slates" [infra-Blaini]." It is added that the latter probably correspond to the middle, and the Blaini conglomerate to the upper silurian.

The section from the Dhauladhár crystallines as far as the southern border of the Zánskár rocks evidently forms a regular ascending sequence. Along that line, however, Colonel Mc'Mahon thinks it probable, from the absence of the trap above the conglomerate, and from the relative thinness of the latter, that an extensive fault must exist. The absence of the trap, if the views taken here of the relations of the Panjál rocks in the Káshmír valley are correct, need not, however, engender this fault, and it seems not improbable that the development of the Blaini conglomerate on the southern, as

compared with the northern side, may equally be due to local thinning out.

The discussion of the Panjál rocks of the difficult section to the southward of the Dhauladhár range may now be undertaken. Commencing at the band of gneiss to the westward of the crest of the Dhauladhár range at Dalhousie, already mentioned in an earlier chapter, this rock is described by Colonel Mc'Mahon[1] as being foliated, and never granitoid. "Next the gneiss comes a rather thick band of decided mica-schists. It is thickest on the south bank of the Rávi, extending from the gneiss to near the stream east of Seru (Sairu). This mica-schist shades rather rapidly into a series of slates and very fine-grained earthy sandstones, terminating next the granitoid gneiss [of the Dhauladhár] in slates, which I believe represent the Simla slates.

. . . .

"In other sections (as for instance at Chuári [Chaohari]), clay slates take the place of the fine-grained earthy sandstones. Within a few miles of Dalhousie itself, on the road to Bakloh, good slates are quarried close to the granitoid gneiss.

"Everywhere the beds immediately in contact with the 'granitoid gneiss,' for a distance that varies in different sections, exhibit more or less hypometamorphism.

"Along a section taken in a westerly direction from Dalhousie the average dip of the silurian beds is N.E., but it varies locally from N.E. 11° N. to N.E. 11° E. As a whole the series dips into the granitoid gneiss all along the line, and, judging superficially from appearances, one would say that it dipped under the gneiss."

1 "Records," Vol. XV., p. 40, *et. seq.*

In describing this junction Mr. Medlicott observes[1] —"For about fifty feet from the granite [granitoid gneiss] the schists exhibit a very marked increase in induration, acquiring a close-grained crystalloid structure. Near the contact, irregular small veins of the granitoid rock are included in this hard contact rock; yet the junction with the main mass is perfectly sharp, indicating no approach to an amalgamation of their ingredients." It is also remarked that the granitoid gneiss has an easterly dip in its centre.[2]

It thus appears that in this section there is on the western side a perfect transition from foliated gneiss through micaceous schists to slates, which in their turn appear to underlie granitoid gneiss, the metamorphism of the slates at the contact being slight, and the junction sharp and distinct.

In interpreting this section Colonel Mc'Mahon arrives at the conclusion that the foliated gneiss on the west of the Dhauladhár range is approximately the same as the generally more granitoid rock of the main range[3]; and that there is an ascending series of the Panjál rocks from the former to the latter, with an extensive fault at the foot of the latter.

It has been already observed in an earlier chapter from the persistence of the north-easterly dip throughout the section, and from the general analogy in the relations of the rocks, and the relative position of the range itself, to the rocks of the Pír-Panjál range, that there is a considerable probability that the rocks of the

1 "Memoirs," vol. III., pt. II., p. 65. 2 *Ibid*, p. 64.

3 There appears a slight discrepancy in Col. Mc'Mahon's description, as he first speaks of the gneiss of the main ridge as preserving its granitoid character up to the junction with the slates on the western side, and later on (p. 44) of this gneiss being foliated on both its borders. If the latter is correct, inversion must almost certainly have taken place.

Dalhousie district have originally been inverted to a very considerable extent. It has also been observed that this view is strongly confirmed by the occurrence of undoubted inversion in the Chamba valley.

From Colonel Mc'Mahon's description it seems perfectly clear that the view of the Panjál rocks overlying the western band of gneiss being in normal relation to that gneiss must be the correct one. On the inversion hypothesis, however, it must be assumed that there is a concealed synclinal axis within that band of Panjál rocks, and that the granitoid gneiss of the Dhauladhár was originally inverted on the former rocks. The sudden junction between slaty rocks, and granitoid gneiss, on the western side of the Dhaulhadhár range is so different from the junction observed between the schists and the foliated gneiss on the western side of the band of Panjál rocks, that there is probably some abnormality. The above mentioned explanation of Colonel Mc'Mahon assumes the existence of a fault on the outer border of the gneiss of the main axis, cutting out the lower part of the Panjál rocks, and bringing their middle part (Simla slates) into direct contact with the gneiss. Without denying that this explanation may be the correct one, another explanation will be proposed in the following chapter, apparently fulfilling all the requirements of the case, and not involving the necessity of introducing an extensive fault.

Before the question can be finally decided as to whether the foregoing interpretation of the relations of the whole of the Dalhousie rocks is the correct one, it will be necessary to carefully trace these rocks into connection with the rocks of the Pír-Panjál range at Banihál. There can, however, be no question but that if this interpretation can be maintained, the two sections will be much more in harmony than on any other view. Thus in the Pír-Panjál the strata will have been thrown into one great fold inverted on its southern side, followed

to the north-east in the valley of Káshmír by a series of similarly inverted minor folds. In the Dhauladhár, in place of the one great fold of the Panjál rocks, the flexures will have opened out, forming originally a major fold in the heart of the range, with several minor folds on the southern side; all being inverted on the one or the other side. On the north-eastern side the major fold will have been followed in the valley of Chamba by a series of similarly inverted minor folds.

To the north-westward of the Rávi valley the Panjál rocks have been traced along the outer border of the Middle Mountains into connection with the corresponding rocks of the Banihál section. The mode of disappearance of the band of gneiss occurring in the trans-Rávi district, between the Panjál and Zánskár rocks to the south-west of the Dhauladhár, is, however, at present unknown. None of this gneiss occurs, as far as is known, in the neighbourhood of Sud Mahádeo, where it is believed the Zánskár and Panjál rocks are in contact. The Panjál rocks of Chamba have been traced as far as the town of Bhadarwáh, where they have a general north-easterly dip, and it is probable that similar rocks are largely developed in southern Kishtwár and northern Bhadarwáh, which have not yet been geologically examined, although a hasty traverse of these districts was made by Dr. Stoliczka.[1] The south-eastern side of Chamba, and the district of Barmáwah (Barmaor) is likewise almost a *terra incognita* in a geological sense. Beyond the immediate flanks of the Dhauladhár Colonel Mc'Mahon has, however, recorded an outcrop of the upper Panjál traps at the village of Hul, to the north-north-east of Chamba, and of the (Blaini) conglomerates some distance to the south-west of the former place. It is probable that the Panjál rocks,

1 "Memoirs," Vol. V., p. 350.

interpenetrated by the extremity of the Kulu gneiss (beyond the scope of this memoir), are largely developed in Barmáwah.

Returning to the consideration of the Panjál rocks of the Chínáb valley above Kilár, it will be found that the slates overlying the gneiss at that place continue with the same strike as far as Sauch, where they are thick-bedded, and contain occasional bands of splintery greyish shales. The strike at the last-named spot has resumed its normal north-westerly direction, the dip being to the south-west. At Saor a synclinal axis, which is again met with higher up the river near Sheli, occurs in nearly vertically bedded slates. Between these two places there are a considerable number of bands of bluish-grey and fawn-coloured sandstones interstratified with the black flaggy slates. Between Tindi and Sheli the slates contain large quantities of iron-ore, partly in the form of magnetite; and sandstones with occasional bands of blue limestones are of not uncommon occurrence. In the thick-bedded slates in this region there are embedded a vast number of pebbles, blocks, and boulders of granitoid rocks, either angular or water-worn, and varying in size from less than an inch to upwards of three-and-a-half feet in diameter. These granitoid pebbles and boulders extend through a great thickness of rock, and over a wide horizontal area, being found on the same synclinal axis at Saor and Sheli, although they are much less numerous at the former spot and appear to be entirely absent in the same rocks further to the north-west. The occurrence of a similar granitoid boulder in the conglomerates of Chamba, coupled with the position of these beds near a synclinal axis, and their underlying beds containing calcareous bands, indicates the probability of these rocks being the same as the conglomerates of Chamba, and consequently the representatives of the Blaini and Múth horizons. The gradual

passage from beds thickly filled with pebbles and boulders to beds of pure slate, and the circumstance that the conglomerates are not immediately succeeded by the Zánskár rocks appears to indicate that the conglomerates of the Chínáb form a connecting link between those of Chamba and of the Panjál range, where they appear to range lower down in the section.

From the great number and considerable size of many of the granitoid pebbles and boulders in the slates of Sheli, it seems very difficult to account for their mode of occurrence without the aid of ice as a transporting agent. This supposition is countenanced by the presence of ice-worn boulders in the Talchír rocks of peninsular India, probably belonging to some part of the early mesozoic period. Colonel Mc'Mahon compares the typical Blaini conglomerate of the Simla area to a "boulder bed."

Above the synclinal axis of Sheli the Chínáb flows along the line of an anticlinal axis as far as Triloknáth, another synclinal occurring about seven miles above that place. Between Triloknáth and Tandi, where the Chandra and Bhága rivers unite to form the Chandra-Bhága, or Chínáb, the rocks have a south-westerly dip, and consist mainly of dark slates. Among these slates to the south of Tandi a large mass of blue limestones, carbonaceous shales, and a few pale-coloured sandstones, overlies the southerly-dipping slates, and appears on its southern border to be itself again overlain by similar slates. The limestones on careful examination are, however, seen to be folded on themselves, and it appears most probable that they form a compressed synclinal, the slates on the southern border having been bent over and inverted on the limestones. A patch of the same rocks caps the slates to the south-east of Tandi. It is most probable that these limestone and shaly rocks correspond in the main

to the lower part of the Zánskár system, although they may also contain representatives of the upper part of the Blaini division of the Panjál system. Dr. Stoliczka has suggested[1] that these rocks may correspond to the Krol limestone, in which case they must include representatives of the upper part of the Zánskár system, or supra-Kuling series. They are all provisionally coloured on the map as belonging to the Kuling series. It is noteworthy that these rocks are not immediately underlain by the Blaini conglomerate, showing the inconstancy of the petrological characters of that member in these districts. The south-easterly extension of the slate series of the Chandra is beyond the scope of the present memoir, but it may be mentioned that at the village of Koksar these slates rest on gneiss forming the ridge of the Rotang pass, and probably extending into Barmáwah to the north-west.

To the north-west of Tandi, up the valley of the Bhága, the slates continue for a distance of some ten miles, with a south-westerly dip, and then overlie the gneiss of the Zánskár range, which is here reduced to a few miles in thickness. The junction of the slates and gneiss appears to be a gradual one, but unaltered slates occur very close to granitoid gneiss. Dr. Stoliczka remarks[2] that "the lower beds immediately above the gneiss agree in mineralogical character with the rocks of the Bhábeh series."

The notice of the Panjál rocks of this area may be concluded by mentioning the section between Triloknáth and the gneiss to the northward. The beds of that place, with a north-easterly dip, continue a short distance up the tributary valley to the northward, where the

1 "Memoirs," Vol. V., pp. 340-41.

2 *loc. cit.* On page 341, line 7 from top, it seems that the word *Bhága* should be substituted for *Chandra*.

dip becomes south-westerly: these beds, consisting of the usual slates and sandstones, form a regular descending series, as far as the village of Kurgose, where they gradually assume a micaceous character, and pass into bands of foliated, underlain by granitoid, gneiss, the transition being so gradual that it is difficult to draw any satisfactory boundary between the two series of rocks.

Between the tributary valley north of Triloknáth and the Bhága valley, there occurs a diamond-shaped inlier of granitoid rocks, boulders of which are seen in abundance in the bed of the Miling stream, flowing into the Bhága just above the Moravian missionary station of Kyeling (Kailing).[1] The relation of the slates to the granitoid rocks has not been very closely observed, but it appears probable that the junction is somewhat sudden, and it is unlikely that it can be a faulted one.

Summarizing the results of the examination of the Panjál rocks of the Chamba basin and the Dalhousie district, it may be observed that these rocks are of great importance in connecting the older palæozoics of the Káshmír valley and of the Simla and Spiti districts. They leave no room for doubt as to the identity of the Panjál rocks with the Blaini and infra-Blaini series of the former, and the Múth and Bhábeh series of the latter area. They seem further to indicate that the Blaini conglomerate of the Simla district may either be strongly developed at the top of the series, or that it

1 The author trusts he may be pardoned in mentioning here his gratitude to the Moravian missionaries of this little station—and especially to the Rev. A. W. and Mrs. Heyde—for their grateful hospitality, which has been extended to him on more than one occasion. Only those who have experienced it can appreciate the pleasure with which the solitary traveller who has traversed the barren wilderness between Ladákh and Láhol arrives at the charming little oasis which the missionaries have created, where he is received with the heartiest welcome.

may occur less strongly developed among the slates themselves, or finally that it may be represented by slates alone. The lower part of the system, next the underlying gneiss, may apparently consist either of mica-schists, or of little altered slates, which would seem to be difficult to distinguish from the higher Simla slates. Finally it appears that there is generally a gradual passage from the lower beds of the system into foliated, and then into granitoid gneiss, but that there are instances where the junction is somewhat sudden.

The Zánskár basin.

The next area in which it will be most convenient to consider the characters of the Panjál rocks is the Zánskár basin. In that area these rocks form a continuous band along the south-western border of the basin, at the north-western extremity of which they are in connection with the corresponding rocks of the Káshmír basin at Drás. On the north-eastern border of the Zánskár basin the Panjál rocks can only here and there be detected in their unaltered condition, since to the north-west they are probably in great part concealed by the tertiaries of the Indus valley, while to the south-east a great part of them has been converted into metamorphic rocks, which will be considered in the next chapter.

The description of these rocks may be most conveniently commenced on the Bhága river, at the south-eastern corner of the basin where they are only separated by a comparatively thin core of gneiss from the corresponding rocks of the Chamba basin, described in the last section. To the north of the Bhága gneiss the slaty rocks are precisely similar to those on the south, and, as already mentioned, the lower beds were identified by Dr. Stoliczka with the Bhábeh series of Spiti. There is an ascending series of the Panjál rocks in the direction of the Bárá-Lácha (Baralatse) pass; and on

both sides of the latter nearly horizontal strata of yellowish light-coloured and blue limestones, and white and purple quartzites and sandstones cap the ridges and overlie the slates. In fragments of these limestones to the westward of the pass Dr. Stoliczka obtained[1] "traces of *Trilobites* and *Orthis*," and thought it probable that these rocks might belong to the Bhábeh, or possibly to the Múth series. The former determination is very improbable, as these rocks are so far removed from the gneiss, and it seems much more likely that these rocks, like the limestones of Tandi, which they closely resemble, belong to the upper (Múth) part of the Panjál system, and to the lower (Kuling) part of the Zánskár system. Judging from rock-specimens in the Indian Museum collected by Dr. Stoliczka in this district and in Spiti, and from his own writings[2] it seems that, in the absence of characteristic fossils, it is frequently extremely difficult to distinguish the Kuling light-coloured, and mostly whitish, quartzite from the topmost beds of the underlying Múth series. From the above facts, and from their resemblance to the basement rocks of the Zánskár system at Lingti, it seems probable that the limestones, sandstones, and quartzites in the neighbourhood of the Bára-Lácha contain representatives both of the Múth and Kuling series, and thus form a complete transition from the Panjál to the Zánskár system. On the map they have been coloured as belonging to the Kuling division of the latter, but this must merely be considered as provisional, and only serving to indicate the distribution of these rocks on the top of the slates. The resemblance of these quartzites to those of the top of the Margan pass, between the Káshmír and Wardwan valleys, will be apparent to the reader, and lead to the conclusion that they probably both represent a part of the Múth series.

1 "**Memoirs**," vol. V., p. 24.

2 *Ibid loc. cit.*

To the north-west the Panjál rocks of the Bára-Lácha have been traced by Dr. Stoliczka through Padam to Kartse,[1] although no precise description of their petrological characters has been given. From specimens in the Indian Museum it seems, however, that these rocks consist of the usual slates and sandstones, showing some signs of hypometamorphism. It has been already mentioned that the Kuling zone marked on the map to the north-east of Padam is stated by Dr. Stoliczka to consist of a greenstone-like rock, probably corresponding to some of the Panjál traps of the Káshmír valley, which has obliterated the proper Kuling rocks. The blue area (k) near Padam probably, therefore, corresponds at least in part to the upper part of the slate-coloured area in certain parts of the Káshmír valley, as at Mánas-Bal. In the districts of Rundum and Kartse the Panjál rocks consist almost entirely of blackish slates, frequently very thin-bedded, which to the north-west imperceptibly pass into the trappoid rocks of Drás, already described.

On the north-eastern border of the area of pre-tertiary rocks of the Zánskár basin the only region to the north-west of the Zánskár river where the Panjál rocks have been recognized, is in the neighbourhood of the village of Láma-yúru. In that district the Panjál rocks are much involved with the tertiary traps, and it is frequently very difficult to distinguish the one from the other. The best section is displayed in the steep and narrow ravine leading down from Láma-yúru to the valley of the Indus below Khalsi. The description of these rocks may be best taken from the notes of Dr. Stoliczka,[2] who, after mentioning that the Kuling (carboniferous) rocks extend from the Fotu pass down to Láma-yúru, observes that "for

1 "Memoirs," vol. V., p. 346.

2 "Scientific Results of Second Yarkand Mission.—Geology," p. 14.

more than a mile after leaving Láma-yúru there are extensive shaly deposits, some of them well stratified; they reach to about 300 feet high on the slopes. The shales are at first in places very carbonaceous, and when decomposed they are covered with a white efflorescence of soda and alum. About two miles, or a little more further on, these carbonaceous shales overlie nearly vertically bedded green and red shales; the latter alternate with beds of strong green sandstone, very similar to the 'green-rock,' and the whole group evidently represents the Bhábeh series, just as the former does the Múth series. In one place only I saw, in the Bhábeh slates, a bit of an impression, something like a portion of a *Trilobite*; and in another place I got a few traces of worms. These Bhábeh slates, shales, and sandstones are variously contorted, but for the most part approach the vertical position, dipping highly towards the south or south-west. Towards the Indus the Bhábeh series is cut off by [tertiary] serpentines, which reach down to the valley." The observations of the present writer indicate that the tertiary traps interpenetrate the Panjál rocks more frequently than is the case according to Dr. Stoliczka's description. The Panjál rocks can be traced among these traps for a few miles on either side of the Láma-yúru gorge. Among these rocks may be detected representatives of the ribband-jasper mentioned above as occurring between Drás and Tilel, and also of the trap, or trappoid, rocks of the former place, so that there can be no doubt that these rocks as a whole correspond to the Panjál system of the Káshmír valley, and, therefore, serve as connections between the latter and the Múth and Bhábeh series of Spiti. As far as the observations of the present writer go, the base of the Panjál rocks of the Láma-yúru gorge is not exposed, but Dr. Stoliczka[1] thought it not improbable that they

1 *loc. cit.*

might be underlain in the neighbourhood of the gorge by remnants of gneissic (syenitic) rocks.

It is important to observe that in this section, which must certainly contain representatives of the whole of the Múth series, no traces have been recorded of the conglomerates and light-coloured quartzites characteristic of the higher beds of the typical Múth series. This is again indicative of the inconstancy of all the petrological characters of those rocks, and hence of the great difficulty of distinguishing the two divisions of the Panjál system.

It may also be observed that the middle and lower portions (Bhábeh) of the Panjál rocks of the Láma-yúru gorge are absolutely indistinguishable from representatives of the so-called Attock slates occurring at Kálabágh, on the road from the hill-station of Murree to the military station of Abbotabad in the Hazára district of the Punjab.[1] This identification leads to the conclusion that the Attock slates are in the main the equivalents of the Panjál system of Káshmír territory; a conclusion which might, perhaps, have been arrived at solely from the proximity of the Panjál rocks of the lower Kishanganga valley to the Attock slates of the lower part of the Kúnhár (Khágán) valley.[2]

The Attock slates, it may be observed, have usually been considered as of silurian age, but Dr. W. Waagen[3] has suggested that they may be of carboniferous age, his suggestion being based on the evidence of a carboniferous brachiopod, embedded in dark shale, and alleged to have been obtained from the Punjab. The evidence connecting this fossil with the Attock slates is, however, not altogether inassailable; but perhaps a way out of the difficulty may

1 See Wynne, "Records," vol. XII., p. 208. 2 *Ibid*, map facing p. 132.
3 *Ibid*, pp. 183-5.

be found by considering that the Attock slates may represent a part of both the carboniferous and silurian periods, and that the former division may correspond to the higher part of the Panjál system of the Káshmír territories, which has been shown to be intimately connected with the carboniferous (Kuling).

After this almost unavoidable digression, the consideration of the Panjál rocks of the north-eastern side of the Zánskár basin may be resumed. The next development of these rocks occurs some distance to the south-eastward of the Zánskár river, their most northerly extension being found in the valley of the tributary Markha river, forming a wedge-shaped mass between the two branches of the Kuling rocks. At the extremity of this wedge the Panjál rocks consist of the usual dark-coloured slates and sandstones; and the same rocks are found underlying the Zánskár rocks of the Toglung pass, affected only very slightly by metamorphic action. To the south-west of the pass, however, these slaty rocks on the southern side of an anticlinal on the Zarra river gradually assume a gneissoid character; the crystalline rocks frequently occurring in lenticular masses among the slates. The mingled gneiss and slates are overlain to the south by the Kuling rocks, with a passage from the one to the other. There is, therefore, no question but that at all events some part of this gneiss, which extends far to the south-east, is the equivalent of the Panjál rocks: since, however, it is quite possible that an older gneiss exists with it, and since it has been found generally impracticable to satisfactorily distinguish on the map these two kinds of gneiss in other regions, it has been thought better to colour all the Rupshu gneiss of the same tint as the other metamorphics: its further consideration will be reserved for the next chapter. It may be observed that the direction of the strike of the slates and gneiss of Rupshu is continuous with that of the Panjál

rocks of Láma-yúru, and it is, therefore, probable that these rocks are in connection beneath the tertiaries of the Indus valley.

The Chángchenmo basin and the Ladákh range.

The next area in which the Panjál rocks may be considered is the southern side of what has been termed the Chángchenmo and Kárákoram basin, and the district between that and the summit of the Ladákh range. The clearest sections exhibiting the relationship of the unaltered Panjál rocks of this area to the gneiss which is so extensively developed in northern Ladákh are to be found in the neighbourhood of Tánktse (Tankse) and the Pángkong lake. To the south of Tánktse itself, which is situated on a tributary of the Sháyok some forty miles to the eastward of Leh, a porphyritic granitoid rock is overlain by a great thickness of white and greenish quartzitic sandstones, black and green slates, ribband-jaspers, a few quartzitic conglomerates, and the peculiar so-called "green-rock" of Drás, which it has been shown is probably in part of volcanic, and in part of detrital origin. The whole of these slaty rocks, both in petrological character, and in their relative position to the gneiss, correspond so exactly to the Panjál rocks of Drás that there can be no question but that they are equivalent deposits. These Panjál rocks form a long narrow semi-elliptical strip, extending from the south-east of Tainyár (Tayár, some twenty miles north-west of Tánktse) to the neighbourhood of the Pangúr lake, where they unite with the Panjál rocks of the Pángkong lake, the Tánktse crystallines dying out to the south-east. The central line of the area of Panjál rocks south-east of Tánktse shows here and there a crystalline core forming the highest peaks of the ridge. In the Harong valley the northern boundary of the Panjál rocks appears to be a faulted one, as on the northern side of the valley there are hills of gneiss with a

north-easterly dip, while on the southern side there are the Panjál rocks underlain along the bottom of the valley by gneiss with a south-westerly dip. This fault is apparently continued far to the south-east, but appears to die out to the north-west of Tánktse, the slates there resting conformably in a synclinal in the crystalline rocks; the dip of all the rocks on the southern border of the Panjál area being to the north-east. Some of the Panjál rocks, apparently lying in the middle of the series, have been locally altered into a fine-grained, dark-coloured, and generally crystalline gneiss, quite distinct in character from the underlying white granitoid gneiss, and perhaps corresponding to some of the higher gneiss of Rupshu.

To the north-east of Leh, on the crest of the Ladákh range in the neighbourhood of the Khardong and Laswan passes, the white granitoid gneiss, with a north-easterly dip, forming the great bulk of the range, is overlain by variously coloured bands of schistose gneiss, succeeded by an imperfectly crystalline, dark-coloured, and fine-grained gneiss, alternating with partially metamorphosed, and occasionally totally unaltered slaty beds, probably corresponding to the Panjál rocks, and occupying a synclinal ellipse in the white gneiss, the boundaries of which are approximately indicated on the accompanying map. No other representatives of the Panjál rocks can be identified with any approach to certainty in the neighbourhood of Leh, although it will be shown below that it is highly probable that some of the higher beds of the gneiss may be their altered equivalents.

Returning to the Panjál rocks in the Tánktse district, it is found that near the Pangúr lake (where they are largely developed, and to the southward of which they are overlain by the probably Zánskár rocks of the Tsáka pass, already described) these rocks sweep round

the south-eastern extremity of the gneissic ridge of Tánktse, which they conformably overlie, and are found largely developed on the northern side, in the neighbourhood of the Pángkong lake. On the northern flank of the above-mentioned gneissic ridge, to the north-east of Tánktse itself, the higher gneissic beds, with a north-easterly dip, gradually become interstratified with nonmetamorphic slates, sandstones, and jaspideous rocks, till finally all traces of the crystalline rocks disappear, and the series consists solely of typical Panjál rocks, like those to the south-west of Tánktse. The transition from the crystalline to the slate series is so gradual and imperceptible that it is extremely difficult to draw any satisfactory boundary between the two series of rocks. On the same line more to the south-east, along the south-western shore of the Pángkong lake,[1] the junction between the metamorphic and slaty rocks appears to be either an inverted or a faulted one, the black slates and green shales and sandstones, which form a narrow band along the south-western shore of the lake, dipping towards the gneiss. Still further to the south-east, as

[1] It may not be out of place to mention incidentally the magnificence of the scenery on the shores of the Pángkong lake, which if it were but in any less inaccessible region would attract crowds of visitors, whereas it is only visited by a comparatively few hardy sportsmen and travellers. The rock scenery of parts of Ladákh for its striking contrasts of colour is probably unsurpassed in the world, but when to this is added the presence of a large sheet of water, like the Pángkong lake, the whole effect is then inconceivably magnificent. Standing at the north-western end of the lake at Lukung, the traveller has for the foreground a smooth beach of dazzling white quartz-sand, some two miles in length, beyond which lies the broad expanse of the clear blue water of the lake, sparkling in the brilliant sunlight, and blending softly in the far distance with the horizon; while on either side there rise up picturesque and rugged cliffs of the brilliantly coloured slate rocks, bounded on the south-west by the more sombre gneissic crags of the higher range. The contrast of the white beach, of the blue water, and of the many coloured barren rocks around, seen under the dazzling light of a sub-tropical sun, forms an impression on the memory of the fortunate beholder, too deep to be expressed by words, and the recollection of which can never be totally effaced by any other scenes, be their beauty what it may.

already mentioned, the junction once more appears to be a normal one. In regard to the petrological characters of the rocks surrounding the Pángkong lake there is a great deal of variation, but with the exception of the presumably Zánskár rocks at the north-western extremity, noticed in an earlier chapter,[1] they consist mainly of highly coloured slates, shales, and sandstones. On the north-eastern shore, in addition to the rocks occurring on the opposite side, there are ribband-jaspers and the trappoid rock of Drás: the slates frequently weather to a rusty red colour, like some of the rocks at the latter place.

To the north-eastward the Panjál rocks of the Pángkong lake are bounded by a ridge of gneiss, running with the normal Himalayan strike on the line of the Másemik pass. To the south-east of the Tátar camp at Chagra the Panjál rocks appear to be faulted against the gneiss of the Másemik pass, but on the north-western side of a spur of the gneiss running towards the south from Chagra the same rocks conformably overlie the gneiss. The highest beds of the gneiss are schistose, and frequently garnetiferous; they pass gradually upwards into the Panjál rocks, and downwards into the granitoid gneiss of the Másemik pass. This ridge of gneiss seems to form an anticlinal axis, since on the northern side of the pass it is again conformably overlain by the Panjál rocks, which continue down to the left bank of the Chángchenmo river at Tsolu. The transition beds between the granitoid gneiss and the typical Panjál rocks are described by Dr. Stoliczka[2] in this region as consisting of syenite-schist, passing upwards into chlorite schist, alternating with quartzose schists of great thickness. Intimately connected with these schists "is a greenish chloritic, partly thin-

1 *Supra*, p. 185.

2 "Scientific Results of Second Yarkand Expedition—Geology," p. 16.

bedded, partly more massive rock, which very closely resembles a similar rock found about Sirínagar. Only in this case certain layers, or portions of it, become often distinctly or even coarsely crystalline, sometimes containing bronzite sparingly disseminated, and thus passing into diallage. This chloritic rock forms the greater part of the left side of the Chángchenmo valley, and also occurs south of the Sasser (Sáser) pass." From the summit of the Másemik pass to the bed of the Chángchenmo river there is a regular ascending series of the Panjál rocks; the trappoid rocks occurring, as in the Káshmír valley, in greatest force at the top of the series. A short distance north of the pass some of the Panjál rocks have been locally altered into a dark schistose gneiss, similar to that already described in the Tánktse valley. On the Chángchenmo river at Tsolu the Panjál rocks appear to be faulted against rocks of the supra-Kuling division of the Zánskár system, but to the eastward of Kyám the rocks of the Kuling series apparently intervene and bring the two systems into normal sequence.

In all these sections it is extremely difficult to draw a satisfactory boundary between the typical Panjál rocks and the subjacent gneiss, owing to the complete transition effected from the one to the other by the schistose rocks; the boundaries given on the map must, therefore, be considered somewhat in the nature of arbitrary ones. The observations of Dr. Stoliczka and the present writer indicate pretty conclusively that the massive trappoid rocks on the Chángchenmo river are the equivalents of the traps of the Káshmír valley, but to what extent these rocks owe their origin to true lavas, to volcanic ashes and scoria, and to true detrital sedimentary matter altered by subsequent metamorphic action, it will require very careful microscopical examination to determine.

The Panjál rocks of the Pángkong lake and the south side of the Másemik pass appear to die out among the gneiss to the north-west of the Sháyok. The corresponding rocks between the Másemik pass and the Chángchenmo river are in all probability continuous with the Panjál rocks mentioned by Dr. Stoliczka as occurring to the south of the Sáser pass: this presumed connection has been conjecturally indicated on the accompanying map.

Baltistán.

The last region where more or less unaltered representatives of the Panjal rocks exist is in central and southern Baltistán, where they occur in patches from the south of Skárdu, across the plateau of Deosai, to the valley of the Shingo river, where they are in connection with the Panjál rocks of Drás, and the southern side of the Zánskár basin, already described. On the Drás river the Panjál rocks continue unaltered as far as the village of Dundul (Dandál): they are frequently jaspideous, acquire a black "river-glazing," and disintegrate into a dark and heavy iron-sand. Occasional beds of the true slates are highly ferruginous, and weather to a rusty-red colour, and there are a few beds of the coarse conglomerate of the Pír-Panjál range. Below Dundul these rocks gradually assume a hornblendic character, and not unfrequently contain crystals of hornblende of large size. Lower down the river near Tashgám the strata are thrown into a series of parallel folds, the beds at the base of each anticlinal consisting of dark schistose syenitic gneiss, overlain by the typical Panjál rocks, the transition between the two being gradual and imperceptible. From Tashgám nearly to the junction of the Drás with the Shingo-Shigar river, there are numerous alternations of small anticlinals of gneiss overlain by the Panjál rocks. Near the junction of the two rivers a massive light-coloured granitoid gneiss underlies the schistose transitional rocks. To the north-west the Panjál rocks

of the Drás river extend in a narrow strip a long distance up the valley of the Shingo river, apparently resting in a synclinal of the gneissic rocks, and the junction being gradual and indistinct, as is the case to the north of Drás. The partially metamorphosed Panjáls of Tashgám when traced to the north-west lose their metamorphic character, and present the normal appearance of those rocks.

Turning to central Baltistán and Deosai, and taking a section across the strike from Skárdu to the southward, the rocks first met with in the ravine leading to the Burji (Búrgi) pass are black and green slates intermingled with the trappoid rock of Drás, and overlain by a synclinal of presumably lower Zánskár rocks, on the southern side of which the Panjál rocks are repeated, and to the south of the Burji pass are underlain by a light-coloured and frequently porphyritic granitoid gneiss. On Deosai several patches of the Panjál rocks, the limits of which are only very approximately indicated on the accompanying map, are found resting on the granitoid gneiss. These rocks consist of slates, conglomerates, and trappoids; and pebbles of gneiss are not uncommon in the conglomerates, which probably correspond to some of the conglomerates of the Pír-Panjál range. The junction between the Panjál rocks and the granitoid gneiss of Deosai appears to be a sudden one; although as far as it can be detected the dip of all the beds is in the same direction.

In northern Baltistán and elsewhere there are large areas of gneissic rocks, some of which undoubtedly correspond to the Panjál rocks, but as it is frequently extremely difficult to distinguish these from the subjacent gneiss it has been found more advisable to describe all these metamorphic rocks in a separate chapter.

Summing up briefly the chief characters of the Panjál rocks as given above, it appears that these rocks always underlie the Kuling (lower carboniferous) division of the Zánskár system, and that they consist mainly of dark slates, sandstones, quartzites, conglomerates, and volcanic rocks. The latter are generally most strongly developed at the top of the system, and, although frequently varying greatly in their degree of development in adjacent spots, they can be traced over a very extensive area of country. They appear to attain their most typical development in the neighbourhood of the valley of Káshmír, and on the outer flanks of the Middle Mountains. The higher beds of the conglomerates almost certainly correspond to the Blaini conglomerate of the Simla area, but the development of this characteristic bed appears to be very inconstant. Inferiorly the Panjál rocks are in general partially metamorphosed and rest on gneissic rocks, the junction being very generally a gradual one, and a dark foliated gneiss passing up into schists forming a transition between the true slaty rocks and the subjacent granitoid, and frequently porphyritic, light-coloured rock. In some instances, however, the junction between the slaty beds and the granitoid rock appears to be an abrupt one, but even in such cases there are now in general no well-marked signs of unconformity, the dip of the slaty rocks and of the subjacent rocks being invariably in the same general direction. That some of the Panjál rocks were deposited in comparatively shallow water and in proximity to land is indicated by the occurrence of ripple-marked beds, while, perhaps, the same conclusion may be drawn from the occurrence of some of the conglomerates. Other conglomerates lead, moreover, to the inference that ice-action was probably extant in the Panjál seas as a means of rock-transport. That land, composed of crystalline rocks, existed at

Summary.

the time of deposition of the Panjál system is indicated by the presence of crystalline pebbles in the latter; while contemporaneous denudation of the Panjál rocks themselves is indicated by similarly situated blocks and pebbles of the slaty rocks. From the remarkable general constancy of the petrological characters of the Panjál rocks, it would seem highly probable, although not certain, that these rocks formerly extended over the greater part of Káshmír territory, the old crystalline land probably existing in the form of islands.

Although palæontological evidence is unfortunately not available, the petrological characters and stratigraphical position of the Panjál rocks are fortunately sufficient to prove their correspondence with the Blaini, supra-Blaini, and some of the underlying schistose rocks of the Simla area; with the Múth and Bhábeh series of Spiti; and also, at all events partly, with the Attock slates of the Punjab. It is, however, not generally practicable to indicate these subdivisions in most parts of Káshmír territory. The great bulk of the system in all probability corresponds homotaxially with the silurian of other parts of the world, although it is quite probable that their higher beds may represent a part of the lower carboniferous, while their lower beds may be the equivalents of part of the cambrian system, although none of the characteristic fossils of the latter system have hitherto been detected in India. According to this view the lower azoic Bhábeh rocks will also be of cambrian age. The conclusions to be derived from the relations of the Panjál rocks to the subjacent crystallines may be more conveniently discussed in the next chapter.

CHAPTER IX.—THE CRYSTALLINE AND METAMORPHIC SYSTEM, OR HYPOGENE INTRUSIVE, OLDER PALÆOZOIC, AND ARCHÆAN ROCKS.

Introductory: the "Central" Gneiss of Dr. Stoliczka: the Dhauladhár range, and Dalhousie district: Kishtwár, the Panjál range, and the Káshmír valley: the Zánskár range: Khágán and Baltistán: Ladákh: Summary.

Introductory.

In the table of geological formations on page 47, and on the accompanying map, the rocks treated of in this chapter are simply termed the metamorphic system. Recent observations have, however, brought to light the fact that many of them are at least to a great extent of purely igneous origin, and it is, therefore, better to term them the crystalline and metamorphic system. From the observations made in the preceding chapters it will be gathered that these rocks belong to more than one geological period, their association under one heading being due to the difficulty of always referring them to their respective horizons. The newer of these rocks are the altered equivalents of the rocks of the Panjál system, and occasionally of higher rocks, while the older probably correspond to the archæan (Huronian and Laurentian) system of European geology. From the uncertainty still existing in many cases as to whether many of the more completely crystalline examples of these rocks are of purely igneous, or of partly igneous and partly metamorphic, or wholly of metamorphic origin, it is very difficult to know what term to employ in describing them. Hitherto they have been generally described as

gneiss, but in some cases they should rather be termed granites. In the sequel these rocks will very generally be alluded to as granitoid gneiss; the application of this term must, however, be taken to convey the idea that while many of these rocks partake of the characters of both granite and gneiss, yet any of them may be either true granite or true gneiss. In describing these rocks it will be found most convenient to mention briefly in the first place the characters of their equivalents in the adjacent areas, where they were first described, and then to describe them in the area forming the subject of the present memoir, commencing with the Dhauladhár range, on the outer border of the Chamba territory.

The "Central" Gneiss of Dr. Stoliczka.

In his oft-quoted memoir on the Geology of the North-Western Himalaya[1] Dr. Stoliczka described, under the name of "central gneiss," the crystalline rocks occurring between the Sutlej at Wángtu and the Bhábeh pass, to the north-east of Simla. At Wángtu itself this gneiss is described as granitoid and porphyritic, and indistinguishable in large fragments from true granite. It is composed of a matrix of white felspar, and white, or greyish-white, quartz, in nearly equal proportions, with large porphyritic crystals of white orthoclase, and a considerable quantity of biotite, the latter occurring in small broken laminæ. Pinkish orthoclase, and occasional traces of muscovite have been locally noticed. These granitoid rocks are traversed by innumerable veins of a true intrusive granite, varying from one to twenty feet in thickness, and in certain districts penetrating up into the higher schists and slates. The principal mineral in these intrusive veins was originally considered to be albite felspar, but subsequent examination has shown that it is really oligoclase.[2] The other chief

1 "Memoirs," vol. V., p. 14, *et. seq.*
2 "Records," Vol. XIV., p. 238-40.

minerals of the granitoid rock are quartz, muscovite, and black tourmaline, all occurring in large crystals; while beryl, garnet, and fluor are less common constituents. The crystals of tourmaline in the Chandra valley are sometimes found in trihedral prisms of a foot in length, but smaller hexahedral prisms are more common. The fluor is generally light-green in colour; the beryl occurs in crystals frequently several inches in length, of a light-blue, or white colour, and very brittle; the muscovite is found either in large white, grey, or brown flakes, or in prisms. The order of crystallization of the minerals found in the granite veins is as follows, *viz.*:—

1. **Muscovite.**	2. **Tourmaline.** (Beryl) (Fluor) (Garnet)	3. **Quartz.**	4. **Oligoclase.**

To the northward of Wángtu, in the direction of the Bhábeh pass, there is an ascending series of the gneiss, with a constant north-easterly dip, and in the higher beds the granitoid character becomes gradually less and less well marked till finally the rock becomes distinctly foliated from the presence of a large quantity of mica. The gneiss extends to within a few miles of the Bhábeh pass, where it is overlain by the rocks of the Bhábeh (lower Panjál) series. The junction was, however, so obscured by snow that it could not be closely observed, but the dip both of the gneiss and the slates is in the same general direction, though the angle of the dip of the former is described as being considerably higher than that of the latter. From the micaceous character of the lower Bhábeh rocks it is not improbable that the junction may be a gradual one.

The name "central gneiss" was applied, both to the foliated and the granitoid rocks underlying the Bhábeh series, mainly from the impression that these rocks were confined to the principal mountain

axis of the North-Western Himalaya; Dr. Stoliczka being of opinion that the gneiss and schists to the southward of the Wángtu gneiss, in the district of Bisáhir and elsewhere, had, geologically speaking, nothing to do with his so-called central gneiss, although they are frequently very similar in structure. The later observations of Colonel Mc'Mahon[1] have, however, shown beyond reasonable doubt "that the crystalline series forming the peaks south of Wángtu, of which the Simla watershed is an offshoot, is the same as that of the main range. The massive granitoid gneiss which, although subordinate, is the most conspicuous member of the series, and thus was unfortunately made its representative member, passes into the north base of these southern peaks above Sangla on the Baspa (which joins the Sutlej north of Chíni), at an elevation of about 10,000 feet; and it emerges on the south base at Lorot (20 miles due south-west from Sangla) at the head of the Pabar valley, at an elevation of about 8,500. In the intervening mountains of Bisáhir, crossed by the Borendo and Rupin passes, the stratification lies flatly, and there must be some 6,000 feet of the gneissose schists [foliated gneiss] overlying the more granitoid rock. Although no granite has been observed here, these are no doubt the same as the "schistose [foliated] gneiss" at the top of the typical granitoid central gneiss of Wángtu.

It should be observed that in some parts of the Simla area[2] the higher beds of the slate (Panjál) series rest immediately upon the granitoid rocks, implying the removal of the 6,000 feet of foliated gneiss normally overlying the massive granitoid rock, and a great overlap in the newer rocks.[3] It has accordingly been inferred that in that area the country before the deposition of the Panjál system

1 See "Manual," pt. II., pp. 596-7. 2 *Ibid*, pp. 604-5.

3 The view of the partly igneous origin of the central gneiss may, perhaps, somewhat modify these conclusions, which are taken from the "Manual."

consisted of a great mass of crystalline rocks, deeply eroded by atmospheric denudation, and gradually submerged beneath the palæozoic waters, and in hollows of which the slates were deposited. It may be further inferred that in the Simla area the "central gneiss" existed as gneiss at the time of deposition of the Panjál rocks, and that the apparent conformity now frequently existing between the two must have been produced by subsequent squeezing and metamorphic action.

The term "central gneiss" as being founded on a misconception is certainly an objectionable one, and the term "lower gneiss" has been suggested as a substitute. The original term has, however, been so generally adopted, while it has the advantage of not indicating any particular geological age, that it appears on the whole better to retain it, and it will accordingly be adopted here. It may be added that since in the typical Wángtu region this gneiss underlies a considerable thickness of azoic rocks placed beneath the fossiliferous lower silurians, while, at all events in certain regions, unconformity must exist between the two, and that it is consequently the oldest known rock in the Himalaya, it is highly probable, as already mentioned, that it corresponds to the archæan system of Europe and America, and it might have been thought that this term might have been advantageously applied to it. It will, however, be shown below that there are good grounds for believing that some of the granitoid elements of the central gneiss are at least of palæozoic age, and, therefore, in this respect it is better to use in general a name for the system which does not commit to any very definite geological age. Still the term archæan, with this proviso, will occasionally be employed.

As it has been already shown that the Panjál system of the

Káshmír and adjacent territories corresponds in the main to the Múth and Bhábeh series of Spiti,[1] it may be taken as tolerably certain that any great thickness of crystallines occurring at the base of the former will correspond in the main to the central gneiss, although there is generally some difficulty in determining to which system some of the transitional metamorphic beds should be referred, as will be more fully noticed below. In cases where the whole of the Panjál system has been affected by metamorphic action it is still more difficult to distinguish between the newer, or Panjál, and the central gneiss.

With these preliminary observations the metamorphic and crystalline system of the area forming the subject of the present memoir may be taken into consideration.

The Dhauladhár range and the Dalhousie district.

The crystalline rocks of the north-western extremity of the Dhauladhár range, and its trans-Rávi extension (which are the only parts of that range coming within the province of the present memoir), have been minutely described by Colonel Mc'Mahon in three papers in the "Records."[2] The two first of these papers deal mainly with the aspect of these rocks in the field; but the third paper[3] (which is not quoted in the introductory chapter, as the present writer only saw the proof sheets after that chapter was printed) deals with the microscopic aspect of the crystalline rocks of the main axis, and of the adjacent metamorposed schists. In the third paper the views

1 The writer is well aware that the thickness of the united Múth and Bhábeh series of the Spiti area is far inferior to that of the united silurian and cambrian of Europe, but the case of the correspondence of the thin Kuling series to the lower carboniferous series of Europe shows that any argument drawn from this point can be of but little value.

2 Vols. XV., p. 44, *et. seq.*: XVI., p. 35, *et. seq.*: *ibid*, part 2.

3 "*On the* Microscopic Structure *of some* Dalhousie Rocks."

held in the previous papers as to the origin of some of these crystalline rocks are somewhat modified, and accordingly the terms applied to these rocks have likewise been altered. In the same paper many of the rocks previously alluded to as granitoid gneiss are termed gneissose granite; and it will accordingly be understood that where these terms are employed they must be generally considered as equivalent. It will on the whole be simpler to give a summary in the first place of the observations recorded by Colonel Mc'Mahon in his earlier papers, and then to give the final conclusions derived from the microscopic examination of the rocks.

It has already been shown in the last chapter that there is one strong core of crystalline rocks forming the main axis of the Dhauladhár range, while a much thinner band runs at some distance to the westward of this, preserving an approximately parallel direction: this western band is separated from the core of the main range by a zone of Panjál rocks, and on its outer border is in contact with Zánskár rocks. The relations of the outcrops of these crystalline rocks have already been partially discussed in earlier chapters. Between Dalhousie and Chamba the crest of the main range consists mainly of granitoid rocks; the core of the crystallines attaining a thickness of about six-and-a-half miles, which is retained in the south-easterly extension of the range. In the opposite direction this crystalline core rapidly narrows as it approaches the valley of the Rávi; its width where it crosses that river above Balai having dwindled down to 250 feet, and near Juind the visible outcrop not being more than 100 feet in thickness. Still further to the north-west the crystalline zone again expands to 500 feet in width, and in the neighbourhood of the Kund-Kaplas mountain, beyond which it has not been traced, it attains still larger dimensions. It is probable that to the north-west the crystallines of Kund-Kaplas are in direct

connection with those of the southern end of the Pír-Panjál range in Kishtwár.

In the neighbourhood of Dalhousie the main zone of crystallines is described by Colonel Mc'Mahon in the following words[1] :— "Speaking generally the gneiss is an ordinary foliated gneiss along both margins of its outcrop, and here the bedding, which conforms to the normal dip and strike of the rock series associated with it, is quite distinct. The gneiss gradually passes into a granitoid rock, in which evidence of foliation may usually be traced; and, although joints are numerous, true bedding is often obliterated. The granitoid gneiss is highly porphyritic, and is undistinguishable from, and doubtless is identical with the 'central gneiss.' Towards the centre of the mass the porphyritic appearance dies out, and along the ridge of Dainkund the rock passes into a fine-grained and perfect granite. There are transitional forms between this and the porphyritic granitoid gneiss; that is to say, we have here and there a more or less porphyritic rock which is perfectly granitic. On the road to Chil the matrix becomes so fine-grained in places that the rock assumes almost the outward aspect of a felspar porphyry.

"Where the mass begins to narrow in its north-westerly direction the rock at the same time gradually loses its granitoid character and passes into an ordinary foliated gneiss, in which porphyritic crystals are, generally speaking, sparse or wanting.

"At times the porphyritic granite obliterates the foliated stratified gneiss, even at the margins of its outcrop, and intrudes into the adjoining schists. Instances of intrusive veins at Dalhousie were described by Mr. Medlicott in the passage already quoted from page 65 of his memoir.[2] I may mention another instance at Dalhousie,

1 "Records," vol. XV., p. 44. 2 "Memoirs," vol. III.

on the cart road near the Bull's Head hotel, where the granite is seen to cut through the beds in contact with it for 2 or 3 feet.

"Trans-Rávi, on the ridge north of Banatu, intrusive veins are also to be seen in the schists close to the gneiss, and here these veins are distinctly porphyritic, indicating that the intruded rock was squeezed into the schistose beds in a viscid and imperfectly fused condition. But it was in the Chuári [Chaohari] section that I observed the most numerous instances of the intrusion of the schists by the porphyritic granite. Here the latter has been profusely squeezed between the beds of schists for a considerable distance from their junction with the crystalline rock, and in some instances the porphyritic granite has cut through them.

"The mineralogical characters of the gneiss will be described more in detail in a subsequent paper on the microscopic petrology of Dalhousie; but I note in passing that, viewed macroscopically,[1] the rock is seen to contain orthoclase, quartz, biotite, and muscovite. In the granitic varieties, schorl, in minute or moderate sized crystals, is pretty abundant. I have also noticed some small garnets, in which respect the rock also corresponds with the 'central gneiss' of the Sutlej valley."

In the trans-Rávi district in the neighbourhood of the Kund-Kaplas mountain, where it has been shown that the crystallines of the main Dhauladhár axis have expanded in thickness, they are described as consisting mainly of a porphyritic and perfectly granitoid rock, much traversed by joints, but without any distinct traces of bedding. This rock is apparently in somewhat abrupt contact on either side with slates or schists, which appear in general to have a

1 In the text this is printed *microscopically*, but is corrected in the corrigenda to the volume.

north-easterly dip on either side of the crystalline rocks, and in one place it was noticed that the granitoid rock had intruded between the bedding of the slates.[1]

To the south-east of Chamba, between that place and Maila (Mahila), "the granitoid gneiss crosses to the right bank of the Rávi, at the bend of the river under Tandola, re-crossing to the left bank near Bania. It passes to the right bank again, beyond Bania, and then continuing its course under Dalgara, and above Korauh, it finally leaves the river near Mahila.[2]

"At the junction of the granitoid gneiss and the slates, the former is granitic, and the latter is [*sic*] indurated, and sometimes silicious and massive. Under Dangera (Dalgara), near the junction of the two rocks, the slates are contorted, and there is a sudden reversal of dip, with more or less local faulting. At the actual junction the dip of the slates is normal. The plane of division between the schistose slates and the granitoid gneiss is not sharp but the granitoid gneiss appears to be blended into the slates by imperfect intrusion."[3]

From Colonel Mc'Mahon's description of the Chamba valley section, given in the last chapter, it is quite clear that the adjacent slaty rocks at Maila, showing signs of intrusion by the granitoid rock, are the lower Panjál rocks. On the southern side of the main crystalline axis at Dalhousie, it has been shown that the rocks adjacent to the granitoid rock are probably the equivalents of the Simla slates (middle Panjál), and it is apparently these that are penetrated by the granitoid porphyritic rock. In the trans-Rávi

1 "Records," Vol. XVI., p. 36.

2 The accompanying map is slightly incorrect in this part.

3 "Records," Vol. XVI., pp. 38-9.

district the slates penetrated by the latter are evidently some portion of the Panjál system.

The resemblance of the crystalline rocks of the Dhauladhár range and its trans-Rávi continuation, both in respect of their position beneath the silurian rocks (Panjáls of Chamba valley), of their mineralogical characters, and of their petrological varieties, leaves no reasonable doubt that they are the same as the central gneiss of Wángtu.

With regard to its present condition Colonel Mc'Mahon, in his first notice, came to the conclusion that a considerable portion of the fine-grained granitoid rock of the Dhauladhár must have once been in a more or less fluid or pasty condition, and that its present intense metamorphism "has been principally produced by granitic intrusion at a great depth below the surface, and that the perfectly granitic portion is the intrusive granite itself." It was then inferred that this intrusive portion had mingled with a foliated gneiss, in consequence of which the latter had also been completely converted to a granitoid condition; the penetration of the intrusive element between the layers of the foliated element having caused the two factors to become so intimately blended that no traces of their originally distinct origin can now be detected. Not only is the fine-grained rock at least in part of igneous origin, but also at least some portion of the porphyritic variety, which, as has been shown, has intruded upon some of the adjacent slates or schists. It is added by Colonel Mc'Mahon that "the white oligoclase granite of the Sutlej and Spiti areas possibly marks a somewhat later stage of the eruptions which effected the conversion of the gneiss into a granitoid rock."

As the results of his later microscopical examination Colonel

Mc'Mahon observes:—"Fifteen specimens of the gneissose granite from various parts of the Dalhousie ridge, exhibiting some typical varieties of structure when examined macroscopically, are seen, when examined with the aid of the microscope, to be mere varieties of the same rock. No essential difference of any kind can be detected between them. All of them contain orthoclase, microcline, plagioclase, quartz, muscovite, magnetite, garnets, and liquid cavities containing moveable bubbles. Six of the specimens contain schorl in some abundance, and all but three of the thin slices contain biotite. In all the quartz exhibits a polysynthetic structure very prominently, whilst all contain crypto-crystalline mica.

"Some of the slices give unmistakeable indications of having been reduced by hydro-thermal agencies to a plastic condition, and exhibit true fluxion structure. It is also important to note that the specimens which exhibit these characteristics most prominently are those which show, when viewed macroscopically, a pseudo-foliation, and have consequently a gneissose aspect.

"The rocks are not true granites, but it does not follow from this fact that they are necessarily of metamorphic origin. Between the deep-seated roots of volcanoes, and the lavas that have actually flowed out at the surface of the earth's crust, there must of course be many gradations. The presence of the crypto-crystalline mica in the Dalhousie gneissose granites, that is to say, the presence of an imperfectly crystallised residuum, seems to indicate their affinity with the felspar porphyries."

Colonel Mc'Mahon then states that one of the specimens is very close to a felspar porphyry. He next quotes Mr. Allport to the effect that the mineralogical changes induced in clay-slates by the intrusion of granite are "chiefly the production in them of some

of the minerals which constitute its own mass; that is to say, quartz, tourmaline, and three kinds of mica; occasionally tremolite, magnetite ('and andalusite?'), and in some localities felspar. The structural changes produced in clay-slates by contact metamorphism, according to Allport, are "*(a)* foliation more or less perfect, with every gradation from nearly straight parallel lines to the most complicated contortions; and *(b)*, concretionary, showing a decided tendency to segregation of both quartz and mica, the result being a spotted schist."

"A precisely similar influence appears to have been exercised by the gneissose granite on the slates in contact with it. As to structure, we have seen that foliation has been produced and 'spotted schists' have been formed; whilst schorl, garnet, dark mica, muscovite, and magnetite have been introduced, or created out of the constituents of the slate.

"As regards mineralogical changes, Allport noticed in the rocks described by him in the paper just quoted,[1] that the strata near the granite were 'far more highly silicated than those at a distance from it,' and he expressed the opinion that 'there can be no doubt that much of the quartz has been derived from the intruded rock.'

"In the case of the rocks under consideration, a study of slice No. 28[2] led me to the conclusion that the crypto-crystalline mica seen in the schists, in contact with the granitoid rock, is due to the injection of matter from the granitic rock into the schists in a gaseous or liquid condition.

1 'Quar. Jour. Geol. Soc.,' vol. XXXII., p. 407,

2 A silicious schistose rock in contact with a vein of granitic rock cutting through the schists.

"Two other points are to be noted: *first*, that though the gneissose granite is rich in felspar, only one small crystal of this mineral was found in the numerous slices of rocks in contact with the gneissose granite examined under the microscope; *secondly*, that though liquid cavities are most abundant in the quartz of the gneissose granite, they are entirely absent from the schists immediately in contact with it, and are almost entirely absent from the schistose rocks below them.

. . . .

"That the absence of liquid cavities in the schistose rocks in contact with the gneissose granite, is due to heat, is rendered highly probable by the fact noted in the foregoing paper that pieces of schorl retain internal evidence that the contents of enclosures in this mineral had expanded by heat and forced their way to the surface.

"We have already seen that whilst the granitic rocks abound in felspar the altered slates in contact with them have not developed that mineral. I have also given my reasons for believing that the gneissose granite was reduced by *hydro*-thermal action to a plastic condition; and that portions which present a decided gneissose aspect exhibit true fluxion structure.

"We have also seen that the schists in contact with the gneissose granite exhibit the peculiarities usually developed by contact metamorphism: that is to say, minerals present in the granitic rock, schorl, biotite, muscovite, garnet, magnetite, and crypto-crystalline mica have been developed in them near their point of contact; whilst the water, which was presumably present in the quartz of the clastic rock, has been driven off by heat. Those facts, it seems to me, render it improbable that the features presented by the Dalhousie rocks are the results of selective metamorphism applied to a conformable series of sedimentary rocks.

"The slaty and schistose rocks between the gneissose granite and the outer band of gneiss, though very varied in macroscopic aspect, present little variation under the microscope. They consist of an admixture of quartz and mica. The quartz contains no liquid cavities. One exception to this only was noted in the case of a quartz plugging, which may have been a pre-existing cavity, and which was probably filled with foreign material from intrusive granitic masses in its vicinity.

. . . .

"The metamorphism of the slate series, as a whole appears to me to be due to regional metamorphism, and it does not seem to require the aid of great heat to explain it, for the action of moderately heated steam seems sufficient to account for the formation of the hydrous micas, the minute prisms of tourmaline, and the addition of quartz to the pre-existing grains of that mineral. The gneissose granite on the other hand has undoubtedly been fused, whilst its action on the slaty series in immediate junction with it has been analogous to the contact action of eruptive granite.

"In conclusion, whilst I am not able to affirm as the results of my investigations up to date, that any of the axial gneiss of the Dhauladhár range is true gneiss, I find that it presents the characteristics of an igneous rock. It has been in a fused condition; it shows fluxion structure; it invades the rocks immediately in contact with it; its structure and composition is uniform over wide areas; and it expands suddenly along the line of strike from a width of 250 feet to a width of 6½ miles. The facts at present known point to the conclusion that the 'central gneiss' is an intrusive rock, and has been squeezed up through a faulted flexure along an axis of maximum strain."

It will be observed that Colonel Mc'Mahon's later conclusions,

derived from microscopic observation, differ considerably from his earlier conclusions, derived from observations in the field, as to the mode of origin of the crystalline rocks of the main axis of the Dhauladhár. There can, however, be no doubt from the microscopical observations that these rocks have been subjected to fluxion, and there is equally no room for doubt that at all events a very great proportion of them are of intrusive origin. There may, however, be some question as to the relative time at which such intrusion, or intrusions, took place, and whether there may not have been pre-existing crystalline rocks at the date of these intrusions.

Now in the first place it is apparent from Colonel Mc'Mahon's descriptions that the date of the intrusion of the granitoid rocks piercing the slates of the Dhauladhár must be of subsequent date to the deposition and consolidation of those slates, and, as already said, it is evident that the latter belong to the Panjál system, while some of them (Simla slates) may correspond to the middle part of that system. The date of the intrusion of some portion of the granite must accordingly be subsequent to, or during the epoch of the higher Panjál rocks; this view is evidently in accordance with the view expressed by Colonel Mc'Mahon when he speaks of these rocks having been squeezed along a line of faulted flexure. It will, however, be remembered that in the last chapter it was recorded that a boulder of granitoid gneiss has been obtained from the higher Panjáls of Langaira, to the north-east of the Kund-Kaplas; that similar boulders have been obtained from the Panjál rocks of Pángi, and of the Pír-Panjál, and in the latter case apparently very low down in the system. The occurrence of these boulders, which are certainly older than the greater part of the Panjál rocks, and can scarcely belong to anything else than the central gneiss, proves that at the time of the deposition of the latter there existed in the

Chamba, Pángi, and Káshmír districts a granitoid rock, which was then being largely denuded, and was probably of igneous origin.[1] Further, since it has been proved that in the Simla region the central gneiss already existed as a crystalline rock, and was largely eroded at the time of the deposition of the Panjál rocks, which were laid down in its hollows, it is almost certain that the denuded rocks whence the Langaira and Panjál boulders were derived, were the same as the central gneiss of Simla. This conclusion is adopted by Colonel Mc'Mahon,[2] and considered to indicate that in the Káshmír and Chamba areas "a hidden unconformity exists between the silurian and the 'central gneiss' series." Seeing, therefore, that the Dhauladhár crystallines are the same as the central gneiss, it may accordingly be assumed that in that area a granitoid and probably intrusive rock existed at the time of the deposition of the Panjál rocks. The crystalline condition of the granitoid rocks at the date of the deposition of the latter further indicates that the former must have attained their crystalline structure beneath the pressure of a great thickness of supra-incumbent rocks; from which it may also be inferred that the granitoid central gneiss exposed at the time of deposition of the Panjál rocks must originally have existed beneath a considerable thickness of foliated rocks which had been removed in many places, before the deposition of the latter. Upon the denuded surface of these primitive rocks the Panjál rocks were probably deposited; but in certain spots the former were still exposed and undergoing denudation. According to the extent to which these primitive rocks, or central gneiss, had been denuded, it would depend whether the Panjál rocks originally rested upon foliated or granitoid

1 It is immaterial whether the source of the Langaira boulder was in the trans-Rávi continuation of the Dhauladhár or in the Zánskár range.

2 "Records," vol. XVI., p. 42.

crystallines. All traces of the original unconformity have in most cases been subsequently obliterated.

Taking it then as proved that in the Chamba and Káshmír areas, there existed both foliated and granitoid rocks older than the Panjál rocks, there remains the consideration of those intrusive granitic elements of the central gneiss of the main axis of the Dhauladhár which are certainly of subsequent date to the deposition of the Panjál rocks. On the southern side of the main axis it is apparently the porphyritic variety which has intruded into the slates, but it is not apparent whether the same is the case on the opposite side. Colonel Mc'Mahon's explanation of the sudden junction between the granitoid gneiss and the (Simla) slates on the southern side of the range (which is in such marked contrast to the gradual junction on the opposite side), is that a fault exists between the crystalline rocks and the slates. According to this view it would appear, assuming (as seems to be the case from Colonel Mc'Mahon's description) that it is the so-called Simla slates that are penetrated by the granite, that the eruption of the latter took place after the formation of the assumed fault (as indeed is stated to have been the case by Colonel Mc'Mahon). Assuming, however, as has been shown on other grounds to be very probably the case, that the Dhauladhár axis is an inverted anticlinal one it is possible that another explanation may replace that of the fault theory.

It has lately been shown by Professor A. Geikie[1] that the cambrian rocks of St. David's, the basement beds of which consist of volcanic rocks, have been folded into an isocline, or inverted anticline, so that in one half of the plication the dip of the strata has been reversed. Through the eastern limb of this isocline an intrusive mass of granite has irregularly risen, which has only

1 "Proceedings Geological Society," April 11, 1883.

produced a comparatively slight degree of metamorphism in the adjacent rocks, although it has completely absorbed the rocks into which it has intruded. Some slight faults may have subsequently occurred but they do not interfere with the general structure of the section.

Now in the case of the Dhauladhár, suppose that the main axis originally formed a compressed and inverted anticline, or isocline, with the original archæan crystalline rocks at its centre, passing up on either side through schists into the unaltered Panjál rocks; and that the band of Panjál rocks between the main mass and the outer band of crystallines formed a compressed synclinal, with unaltered slates (Simla slates) in its centre, and schisty rocks on either side. If it be then supposed that a later intrusion of (mainly porphyritic) granite was irregularly thrust up in the anticline, so that it extended up into and completely absorbed the lower Panjál rocks on the western limb of the anticline, and then came into contact with the middle beds (Simla slates) of the synclinal of Panjál rocks, with some slight intrusion, and altering those rocks in the manner indicated by Colonel Mc'Mahon, then the appearance of the section would apparently be that which it now presents. This explanation would avoid the introduction of what appears to be a purely hypothetical fault; although it is not improbable that local faulting may have occurred here and there. The later granitic intrusions both in the Dhauladhár and the Kund-Kaplas may have been so extensive as to have obliterated almost all traces of the pre-Panjál central gneiss, of which the foliated beds described by Colonel Mc'Mahon[1] in the Rávi valley are now the only traces. Even if the above explanation be not the true one, it still seems probable, judging from the analagous sections to the north-west, that the Dhauladhár forms a compressed anticlinal, inverted on the outer

1 "Records," vol. XV., p. 44.

side, and the Panjál rocks a compressed synclinal, with its eastern limb truncated by a fault.

It does not appear that the foliated gneiss of the Rávi valley is included among the specimens examined by Colonel Mc'Mahon, and it would seem from its mode of occurrence that this rock must almost certainly have originally been of sedimentary origin. Should subsequent microscopic examination indicate signs of fluxion in this rock, it would seem probable that the fluxion must have been produced by the proximity of the granitic intrusions. This rock must in all probability be regarded as part of the original foliated central gneiss: and it is not improbable that the foliated rocks on the borders of the crystallines of the Dalhousie ridge are remainders of the same rock, which have been fluxed by the granitic intrusions.

Irrespective of the question as to the exact relative date and mode of origin of the different factors which appear to exist in the crystallines of the Dhauladhár range and Dalhousie district, the conclusion that, at all events, a very large proportion of these rocks is of intrusive origin, and of later date than the axis itself, is of great importance in explaining the peculiar distribution of these rocks. The absence of any granitoid rock in the Rávi valley points to the conclusion, that the intrusive elements never invaded that spot, or rather never extended up into the rocks now exposed to view; and that these elements attained their greatest development in the Dhauladhár and Kund-Kaplas.

It must, however, be observed that in his first paper Colonel Mc'Mahon was disinclined to accept this view since he observes, "I do not think the sudden expansion of the gneiss from a width of 100 feet to nearly 7 miles, is wholly due to the protrusion of viscid masses of an acid igneous rock into beds of pre-existing

gneiss. Considering that the granitoid gneiss retains its great thickness in its south-easterly extension for so great a distance, its sudden attenuation north of the Rávi is remarkable. The silurian [Panjál] beds between the two outcrops of gneiss maintain much the same average thickness throughout, and as I have seen reason to believe, on other grounds, that a fault occurs along the margin of the gneiss at its junction with the slates, it seems to me probable that the sudden attenuation of the gneiss towards the north-west may be due primarily to faulting."

It must be borne in mind that at the time of writing this passage Colonel Mc'Mahon was unacquainted with the great development of granitoid rocks in the Kund-Kaplas region; and from the conclusions already cited at the close of his third paper it seems that he is now inclined to accept some such view as that given above, although still holding to the existence of a fault along the outer border of the crystallines of the main axis.

The igneous origin of at least a considerable portion of the central gneiss in this district (and what is true of one district is, *cœteris paribus*, true of another), is also of very considerable importance in clearing up some of the difficulties previously experienced in other districts in regard to the relations of the central gneiss and the Panjál rocks. It is, however, a matter of great moment to determine in each locality whether all or any of the porphyritic granite was intruded after the deposition of the Panjál rocks, as in cases where this has taken place it is quite probable that the granite may have absorbed a part of the lower Panjál rocks, since, as in the Dhauladhár, there seems not the slightest reason why its upward extension should have been precisely confined to the upper limits of the original central gneiss. It is of

course manifest that in such cases the porphyritic rock, in place of being the oldest rock in the Himalaya, is newer than the Panjál rocks, and it might, therefore, be argued that the occurrence of this rock can no longer be considered as indicative of the presence of the central, or archæan, gneiss. Since, however, this rock is not one which has shot up in the form of long veins (like the oligoclase granite) through a large thickness of superincumbent strata, but has involved the, at all events partial, fluxion of the rocks with which it is associated, it is essentially hypogene, and it is almost certain that in any case its occurrence must imply, at all events the proximity of, the proper central gneiss. With this proviso there will be accordingly no anomaly in classing this easily recognizeable rock, wherever it is met with, as the central gneiss.

It has been already observed that in many districts the slaty rocks of the Panjál system sometimes appear to rest with but little alteration on granitoid gneiss, and at other times to pass gradually down through a great thickness of mica-schists and foliated gneiss into the more granitoid rocks. These variations may perhaps be explained in part by the greater or smaller amount of the foliated central gneiss which had been removed by pre-palæozoic denudation in districts where there were no hypogene granitic intrusions of post-Panjál date; while in regions where the intrusions of hypogene porphyritic granite took place subsequently to the deposition of the Panjál rocks, the above-mentioned variations may, perhaps, be explained by the greater or lesser amount and upward extension of these intrusions, which in some instances may have absorbed the whole of the remaining part of the original foliated central gneiss, and perhaps the lower Panjál rocks themselves, as is possibly the case in some parts of the Dhauladhár itself. With regard to the above-mentioned transition so frequently existing between the lower

part of the Panjál rocks and the foliated portion of the central gneiss (where that exists), and the consequent difficulty so frequently experienced in saying to which system these transitional rocks should be referred, it seems not improbable that although the Panjál rocks were almost certainly deposited upon an extensively denuded surface of the central gneiss, yet that the rocks forming that surface still retained in a greater or lesser degree some approach to their original horizontal position, and that in any case they had not been contorted, or very extensively folded.

Finally it may be said that the origin of the central gneiss seems to be an extremely complex one, and in place of the granitoid members being, as Dr. Stoliczka considered, its most typical and characteristic form, it appears that the foliated gneiss which generally overlies these, although in some places it has been obliterated, is in reality, the true central, or archæan gneiss; and that, at least in some cases, these granitoid rocks, or certainly the porphyritic varieties, are, as already said, not the oldest rocks in the Himalaya, but are actually younger than some of the Panjál rocks. Practically, however, it will be found, as already observed, more convenient to refer all the granitoid members to the central gneiss, but it will yet require very extensive observations, both in the field and in the laboratory, before the tangled skein of the relations of the older palæozoic rocks and the central gneiss can be wholly unravelled.[1]

1 It may not be out of place to mention that in the island of Mull it has been recorded ("Nature," April 19th and May 3rd, 1883) that a massive red granite passes insensibly into underlying metamorphic schists, and occasionally contains included masses of the latter. It has been concluded from this that the granite is of metamorphic origin, but it seems far more probable that the case is analogous to that of the Dhauladhár and that the granite is really of intrusive origin, and the series has been inverted. The passage from the granite to the schists, as described, is precisely analogous to the relations of these rocks in the Dhauladhár and other parts of the Himalaya.

Reverting once more to the neighbourhood of Dalhousie, a few words may be added regarding the thin band of gneiss to the westward of the main range, the outer boundary of which is considered to be a faulted one, while the inner boundary underlies the Panjál rocks; of which the lower beds have been partially metamorphosed. This gneiss is foliated and never granitoid, and is composed of quartz, orthoclase, and biotite: at times its crystallization is imperfect. It forms a continuous band, of which the north-westerly termination is unknown, and near the Rávi is usually of from 400 to 500 feet in thickness, the dip being regularly in a north-easterly direction. In speaking of this band of rocks Colonel Mc'Mahon[1] never says in so many words that it is the same as the central gneiss; he, however, expresses his opinion that it is not the same as the so-called newer gneiss of Ladákh, and goes on to give reasons to show that the crystallines of the main Dhauladhár axis are not "older" than this gneiss. It seems probable, therefore, that this western band is considered by Colonel Mc'Mahon to be the central gneiss, and to correspond with the foliated portions of the crystallines of the main axis, as displayed in the Rávi valley. As in the latter case, its entirely foliated character may probably be explained by its consisting only of the foliated portion of the original central gneiss, which has escaped more complete metamorphism by the absence of the intrusion of the granitic elements. The passage between this gneiss and the overlying Panjál rocks is a very gradual one, without any traces of the unconformity which must probably have existed between them.

In the trans-Rávi district, to the north of Pudh in the Siava valley, the outer band of gneiss, although thoroughly crystalline, still preserves its non-granitoid character: its dip is at first nearly

1 "Records," vol. XV., pp. 41-3.

perpendicular, but gradually flattens out towards the river. "On the descent to the Sewa [Siava] there is a bed or dyke of fissile trap, about 20 feet wide in the gneiss. It appears to be a decomposed diabase. It is of greenish-grey colour, and its specific gravity is 2·95. Under the blowpipe it fuses readily to a black magnetic bead. The microscope reveals pieces of still unaltered augite here and there. Felspar may be traced in it, but it is greatly altered. A banded, or pseudo-foliated appearance, observable in this rock, is due probably to the infiltration of water along lines of cleavage due to traction or pressure. Along these lines minute granules of quartz—some of them of elongated form—are visible. This mineral is doubtless a secondary product. The quartz does not contain any fluid cavities, which are very abundant in the quartz of the gneiss.

"At the point where the road strikes the Sewa, the gneiss is succeeded by blue, micaceous slate, and as Bani [Banni] is neared, the dip of the strata reverts to N. 11° W. The schistose rocks are of a type commonly seen in the neighbourhood of Dalhousie. The outer band of gneiss is, in this section, some thousands of feet thick."

The Panjál range, and the Káshmír valley.

Beyond the geologically unknown country between the Kund-Kaplas mountain and the Chínáb, proceeding in a north-westerly direction along the line of the Middle Mountains, the first known outcrops of distinctly crystalline rocks are situated respectively to the north-west and west of the town of Kishtwár. With regard to the former, it cannot be affirmed with any degree of certainty whether it belongs to the Panjál or to the archæan system. The outcrop to the westward of Kishtwár is, however, continuous with the gneiss of the south-eastern end of the Pír-Panjál range, and the two may accordingly be considered together.

In the Panjál range the crystallines may be traced continuously from the westward of Kishtwár to a point some distance to the south-east of Gúlmarg. To the north-east of that place there is another comparatively small ellipsoidal outcrop, which does not extend down to the valley of the Jhelam. In the trans-Jhelam continuation of the range (Káj-nág) there is a similar ellipsoidal outcrop immediately north-west of the Jhelam valley, beyond which the crystallines entirely die out. Two sections across the crystallines of the Panjál range have been already described in the last chapter, and it was shown that in all probability the crystallines formed a crushed anticlinal axis, inverted on the southern side, similarly to the explanation given of the Dhauladhár crystallines. Of these two sections, in the one across the Banihál pass, it was shown that the crystalline core passed gradually upwards into the Panjál rocks, and that its superior beds were foliated, while the central beds were granitoid and frequently porphyritic. The resemblance of this section to that of the foliated crystallines of the Rávi valley is so close that there seems little doubt that the greater part of the Banihál gneiss belongs to the archæan system, the central granitoid portion being in part intrusive, although no actual instances of intrusive veins have been recorded. As in the case of the Dhauladhár district, the higher beds of the foliated central gneiss have probably become blended by subsequent metamorphism with the lower Panjál rocks.

In the section across the Pír-Panjál pass the crystalline rocks are of an imperfectly granitoid nature, although they contain interstratified bands of schistose rocks; they are succeeded somewhat suddenly by dark schisty slates with pebbles of granitoid gneiss and other metamorphic rocks. From the Banihál section it is probable that representatives of the central gneiss must occur in the present section, and it may be that the intrusive granite has here invaded

the whole of the remaining part of the foliated central gneiss. Whether the granitoid pebbles in the Panjál slates were derived from the crystalline rocks of the immediate neighbourhood, or whether they were transported from a distance, requires further observations to determine. If they were derived from the immediate neighbourhood, it is probable that the section is not so simple as has been supposed, and that there must be some overlap. The difficulty of halting for more than a few hours on the crest of a pass at an elevation of more than 11,000 feet is the reason why more detailed observations on this important point have not been obtained.

In the two ellipsoidal outcrops of crystalline rocks occurring on the higher ground on either side of the Jhelam valley, a porphyritic granitoid rock is the most prevalent, and, as has been mentioned in an earlier chapter, huge boulders of these porphyritic rocks occur in the bed of the Jhelam itself. This rock consists of orthoclase, of a dead white colour, of milk-white quartz, and of biotite and muscovite. The orthoclase forms the large porphyritic crystals, which generally occur in twins, and are frequently upwards of three inches in length. A comparison of hand specimens of this rock with the granitoid porphyry of Wángtu and the Dhauladhár has shown that the specimens from the three localities are indistinguishable, and there seems, therefore, no reasonable doubt but that they are the same.[1]

[1] Some slight discrepancies will be noticed in the description of the mineralogical constituents of this porphyritic rock from different localities, but this is probably due to error. It is worthy of remark that Dr. Verchére originally described this rock from the Káj-nág as an intrusive porphyry, and that, like so many of the conclusions of that writer, this view now turns out to be, at all events to a great extent, correct. It may also be noticed that the granitoid rock of the Káj-nág presents a remarkable resemblance to the well-known "Shap-granite" of Shap Fells, in Westmoreland: the most distinctive feature of which is the abundance of long crystals of pinkish felspar. (See J. C. Ward, 'Quar. Jour. Geol. Soc.,' vol. XXXI., p. 568; and A. Crofton, 'Trans. Manchester Geol. Soc.,' vol. XV., p. 234.) The Shap granite is clearly intrusive.

It is, therefore, practically certain that the granitoid rocks in the neighbourhood of the Jhelam valley belong to the central gneiss, and are very probably in part of igneous origin. Owing to the extremely inaccessible nature of the ground where these rocks occur, no very exact observations of their relations to the Panjál rocks have yet been obtained. On the southern side of the Jhelam valley there appears to be some foliated gneiss above the granitoid rocks, but whether this belongs to the Panjál system, or to the central gneiss has not been determined. On the northern side of the Jhelam, as far as can be seen, the slates appear to be in close proximity to the granitoid porphyritic rocks, and it would, therefore, seem that the original foliated central gneiss, or such portion of it as now remains, has been entirely converted into a granitoid rock, and that no great metamorphism of the lower Panjál slates has occurred.

To the north of the Jhelam the Panjál rocks appear to dip away in all directions from the central gneiss, indicating that the compression and inversion of the anticlinal axis of the Pír-Panjál range has in this district totally died out.

The absence of the central gneiss *in situ* in the deep valley of the Jhelam is a very remarkable feature, and almost precisely analogous to the sudden contraction of the Dhauladhár gneiss at the valley of the Rávi. On the supposition that the granitoid rocks are at least in part of later igneous and intrusive origin, the mode of occurrence of these rocks is more easily understood than is the case if they are entirely of metamorphic origin.

In connection with this subject it may be observed that in the "Manual of the Geology of India," it is concluded[1] that the valley of the Kishanganga at Muzafarábád, and of the Jhelam below its

[1] Pt. II., pp. 478, 518.

great flexure at that place form the boundary of the Himalaya proper. This conclusion is strikingly confirmed by the occurrence of the bay of tertiary rocks at the mouth of the Kishanganga, and by the gradual but complete extinction some distance to the south-east of the crystalline axis of the Pír-Panjál range,—an axis which can be traced up to that point with but slight interruption from the Dhauladhár range, and as it approaches the valley of the Kishanganga becomes gradually less and less marked until its final disappearance beneath the Panjál and Zánskár rocks of that valley. The crystallines to the westward of the Kishanganga, though belonging to the same geological horizons, are part of an entirely different mountain system, namely, that of the Mustágh and Chilás ranges of Baltistán and Ladákh, which will be described in the sequel.

In the valley of Káshmír itself the only outcrop of crystalline rocks occurs in the small ellipsoidal mass near the mouth of the Sind river, which has already been described in the last chapter. It has there been shown that the granitoid gneiss, which is apparently interstratified with calcareous rocks, seems to occur at the base of a considerable thickness of upper Panjál rocks. Whether, however, this rock corresponds to the central gneiss cannot yet be determined. If it should prove to be the same, it would seem probable that there must either exist considerable dislocation between the granitoid gneiss and the Panjál rocks, or that the higher beds of the latter overlap the former, because the Panjál rocks adjoining the gneiss belong to the higher volcanic portion of that system.

The band of foliated gneiss to the north-east of the Walar lake may be conveniently mentioned here, although it is not within the valley of Káshmír. This gneiss has also been described in the preceding chapter, and has been shown in all probability to occupy a com-

pressed anticlinal at the base of the Panjál rocks, inverted on the southern side. This gneiss may correspond to the higher foliated portions of the central gneiss, the subsequent crushing up of the rocks having obliterated any sign of unconformity. It is, however, possible that it may represent the lowest beds of the Panjál system.

The Zánskár range. The next area in which the crystalline rocks may be considered is the great Zánskár range. In this extensive area the crystalline rocks are found in the Bhága river in Láhol forming a band merely a few miles in width; to the north-west of the Bhága valley this band expands very suddenly in width, and the area of crystalline rocks continues to increase regularly in width up to a point north of Kishtwár, where it has a width of more than fifty miles. Beyond this point it again contracts somewhat rapidly, and terminates at the south-eastern end of the Zánskár rocks of Drás and Tilel. The sudden termination of the crystalline rocks at this point, and the continuation of their axis by a basin of mesozoic rocks is precisely analogous to the termination of the crystalline axis of the Panjál range, and points in the same manner to the dying out of the Himalaya proper towards the north-western end of the Káshmír valley. The Zánskár range, from its position, may probably be considered as the principal continuation of the Himalayan chain from the south-east.

It will be shown that the crystalline rocks of this range contain representatives both of the Panjál rocks and of the central gneiss, although, as is so generally the case, it is often very difficult to distinguish between the two. It will be found most convenient to mention the few facts which are known regarding this great mass of crystallines by commencing on the Bhága river, and thence pro-

ceeding towards the north-west and so round the entire crystalline area.

In the Bhága valley, as has been mentioned in the last chapter, the crystallines, which were recognized by Dr. Stoliczka[1] as the central gneiss, are overlain by rocks corresponding to the Bhábeh series of Spiti. The crystallines are non-porphyritic, and partly granitoid, and partly foliated; the latter forming the higher beds and passing upwards gradually into the lower Panjál (Bhábeh) rocks. The section seems, therefore, to be in the main analogous with the typical Wángtu and Bhábeh section, though the passage from the gneiss to the slates has not been recorded in the latter. All traces of any unconformity between the central gneiss and the Panjál rocks of the Bhága have been completely obliterated by subsequent metamorphic action, and it is probable that the higher gneissic beds belong to the Panjál system. On the north-eastern side of the Zánskár range no close observations of the relations of the gneiss to the overlying rocks have been recorded, but it seems probable that the succession is apparently normal and gradual.

In the districts of Kartse and Suru near the north-western termination of the more distinctly crystalline rocks, some more precise observations have been made. Near the village of Sánkho (Sanku, or Sankoo) in Kartse, there occurs an elliptical dome-shaped mass of white granitoid gneiss, with its long axis directed north-east and south-west, and overlain by schisty slates, having a quaquaversal dip around the gneiss, except on its southern side. The schists, or slates (for there is a gradual passage from the one to the other) are frequently either hornblendic, talcose, chloritic, or micaceous, and extend down the Suru river, where they occasionally pass into semi-gneissic

1 "Memoirs," vol. V., p. 341; in line 7 from the top the word *Chandra* should be *Bhága*.

rocks. They are the same as the hornblendic rocks of Tashgám, on the Drás river, and, therefore, evidently belong to the Panjál system, and are accordingly so tinted on the map. The granitoid gneiss of Sánkho is described by Dr. Stoliczka[1] as being composed of white quartz, orthoclase, and muscovite: biotite being subordinately represented. This granitoid rock is the same as the similar rocks to the north of Drás: its upper portion, which shows some signs of stratification, appears to dip in the same direction as the overlying schisty rocks, but the junction is somewhat abrupt. On the south side of the dome-shaped mass of granitoid gneiss there appears to be a fault separating it from the hypometamorphic rocks of Suru, which incline towards the gneiss. There seems every probability that this granitoid gneiss corresponds to the central gneiss, and may very probably be in part of igneous origin. No traces of the foliated portion of the central gneiss remain.

In the Suru district the metamorphic rocks forming the termination of the crystalline axis of the Zánskár range are of enormous thickness, and consist of micaceous, or hornblendic schists, with occasional bands of a dark-grey, imperfectly crystalline foliated gneiss: some of the schists can scarcely be distinguished from slates, and they are not unfrequently garnetiferous. These rocks appear to correspond to the schists overlying the granitoid gneiss of Sánkho: to the west and southward of Suru they conformably underlie the rocks of the Zánskár system, the Kuling series being sometimes recognizeable at the base of the latter, but very frequently the supra-Kuling rocks, more or less altered, being the first rocks of the Zánskár system that can be recognized. It is quite clear, therefore, that the schists in the neighbourhood of Suru correspond to the rocks of the Panjál system, and in part also to those of the

1 *loc. cit.*, p. 347.

lower division of the Zánskár system. It has, however, been found preferable, in the present state of knowledge, to colour in these rocks with the metamorphic system, as it is impossible to define their southerly limits, where it is probable that representatives of the central gneiss occur. In the neighbourhood of the Bhot-kol pass the rocks are mainly the metamorphosed palæozoics, overlain by the Zánskár rocks. On either side of the pass itself there occur, however, dome-shaped masses of white granitoid gneiss like that of Sánko, which are apparently sometimes overlain by the metamorphic Pánjal rocks, and at others either by the Kuling or the supra-Kuling series. A short distance on the western side of the pass there occurs another mass of the same granitoid gneiss, overlain to the south and west by dark slates, probably belonging to the Kuling series, and by the limestones and dolomites of the supra-Kuling series. On the eastern side there is a thin band of probably the same slates, which in the valley seem to dip towards the gneiss, but higher up in the hills to overlie it. From the similarity of these granitoid crystallines to the crystallines of Sánkho and Drás (described below), it is inferred that they most probably represent the central gneiss. The absence of any signs of intrusion of the crystallines into the Zánskár rocks forbids the idea that they can be of later date than those rocks, and it, therefore, seems, not improbable that these bosses of crystalline rock are remnants of land formed of the central gneiss, which in this spot persisted into mesozoic times. The gneiss of Sánkho may have been a portion of the same land, which was gradually covered up by sedimentary deposits in early palæozoic times; the palæozoic rocks having gradually overlapped the gneiss, and the direction of their bedding corresponding with that of the former. There is great need of fuller observations of these interesting rocks, but here again is the difficulty a geologist experiences

in making any long stay on the summit of a pass 14,500 feet in height, where not even the materials for making a fire are attainable. The foregoing meagre observations leave, however, very little room for doubt that in this region there is a clear case of the existence of the central gneiss as land during the deposition of the palæozoic and some of the overlying rocks.

To the south-east of Suru and the Bhot-kol pass the schistose rocks extend for some distance, but masses of the more granitoid rocks occur more commonly; and there are numerous boulders and pebbles of the latter in the beds of the streams, indicating the prevalence of granitoid rocks in the heart of the range.

The next district where the gneissic rocks of the Zánskár range are known is in the Wardwan valley below Inshin, where they have already been described in the preceding chapter as underlying the Panjál rocks, and passing into them by imperceptible gradations. In the neighbourhood of Máru the gneiss varies very much in character, being either foliated or granitoid, and the latter either fine-grained or porphyritic: pebbles of the granitoid varieties are very abundant in the bed of the Farriabadi river flowing into the Wardwan from the north-east.

Between the villages of Máru and Honzal (Hanza) the strike of the rocks become first north-westerly, and lower down the river almost due north, following very nearly the course of the river: the prevailing rock at Máru is gneiss, while at Honzal it is principally a massive white quartzite. At the great bend of the river some distance below the latter place, the strike again becomes north-westerly, and an anticlinal and synclinal axis occur below Sundar. Gneiss is the most prevalent rock in this district, and is generally very massive and granitoid, especially at Ekali: below that village it is underlain by

massive white quartzites, like those of Honzal. Below Ekali, as mentioned in the last chapter. the junction betwen the metamorphic and the normal Panjal rocks is apparently a faulted one.

That there are representatives both of the foliated and granitoid varieties of the central gneiss among the metamorphic rocks of the Wardwan is highly probable, and it is also certain that the lower beds of the Panjál rocks have been partially metamorphosed. There is, however, at present no evidence to afford a clue in drawing any line between these different crystalline and metamorphic rocks, nor are there any means of deciding as to their mode of origin. It is evident that the great development of metamorphic energy extending up into the mesozoic rocks of Suru did not reach the lower Wardwan valley.

In the valley of the Chínáb, on the southern side of the Zánskár range, the gradual passage of the Panjál rocks into the metamorphic system near Piyás has been already described in the preceding chapter. Between that place and Siri, the rocks consist of alternations of granitoid gneiss with mica-schists, and other schistose rocks: at Seri the rocks are almost entirely granitoid gneiss, while a little higher up the river a white quartzite, like that of the Wardwan valley, is more common. At Atholi (Atúli), opposite the junction of the Bhutna stream with the Chínáb, an anticlinal axis, probably the continuation of the faulted anticlinal separating the metamorphic and Panjál rocks in the lower Wardwan valley, crosses the river, and, taking a north-easterly direction, runs for some distance up the Bhutna valley, where it appears to die out. The strike of the strata on the southern side of this anticlinal gradually changes, till at Atholi it becomes north-easterly, the dip being to the south-west: higher up the Bhutna valley the strike again bends round to its

normal north-westerly direction, the dip being to the north-east. The strata on the western side of this anticlinal in the Bhutna valley maintain their normal strike. In addition to the evidence of a dislocation on the line of this anticlinal afforded by the want of uniformity in the strike of the beds on the two sides, there is also evidence afforded by the dissimilarity in the petrological characters of the rocks on its two sides. The rocks on the right bank of the Bhutna at Atholi are black schisty shales, impregnated with pyrite, underlain higher up the river by garnetiferous schists and granitoid gneiss; while on the left bank they consist of highly micaceous schists abounding in garnets, underlain by granitoid gneissic rocks.

According to notes furnished to the author by Mr. Drew, the metamorphic rocks, sometimes granitoid and sometimes schistose, and with occasional interstratified bands of pure white crystalline limestone, are found the whole way up the Bhutna valley, and across the Umási pass.

Above Atholi, in consequence of the curving of the above-mentioned anticlinal, the Chínáb cuts at first almost directly across the strike of beds of garnetiferous mica-schists and gneiss, but afterwards the strike for some distance regains its normal direction and becomes coincident with the course of the river, the dip on the right bank being to the north-east. Near the village of Shua the strike once more becomes almost due north and south, and a synclinal and anticlinal fold occur, the strike above the latter becoming a little north of west, with a southerly dip, which continues as far as Kilár: the rocks in this part consist of mica-schists, and foliated and granitoid gneiss. At the village of Darwas veins of oligoclase granite, with large crystals of black tourmaline, interpenetrate the schists, generally parallel to the bedding. Immediately to the south

of Kilár a thick bed of granitoid gneiss underlies bluish slaty-schisty rocks of the Panjál system, the junction being apparently conformable and the overlying rocks showing but slight signs of metamorphism.

To the southward of Kilár, on the road to the Sachi pass, Colonel Mc'Mahon describes[1] the Panjál rocks as passing down into quartz and mica-schists, which overlie foliated gneiss. The latter is said to conformably underlie and to intercalate with the schists, the passage between the two being somewhat gradual. Intrusive veins of oligoclase granite, rich in tourmaline, extend up into the schists, which are regarded as the lower silurian, while the foliated gneiss is regarded as the central gneiss.

In the unaltered Panjál rocks to the south of Kilár, as has been mentioned in the last chapter, there occur numerous boulders of granitoid rocks, indicating the denudation of the central gneiss during the deposition of the Panjál rocks, and the probable existence of land at that time in the heart of the Zánskár range.

The exact determination of the upper limit of the central gneiss in this district, as in so many others, appears at the present time impossible. If Colonel Mc'Mahon's reference of the mica-schists of the Sachi stream to the lower Panjál (silurian ?) system, and of the underlying foliated gneiss to the central gneiss, be correct, it would appear that the apparent passage between the two must have been produced by comparatively late metamorphic action, the inducing cause of which may have been the abundant intrusion of the oligoclase granite. If in the neighbourhood of Kilár the same division is marked by the junction of the granitoid crystallines and the schisty-slaty bluish Panjál rocks, which show no signs of intrusion

1 "Records," Vol. XIV., p. 308.

by the granite, it would appear that such portion of the central gneiss as remained at the time of the deposition of the Panjáls had been already highly metamorphosed by granitic intrusions, but that later metamorphic action had not so completely fused together the central gneiss and the Panjál rocks. The existence of land in the centre of the Zánskár range during the deposition of the Panjál rocks will imply the overlap of the latter on the central gneiss, and it is much to be desired that future observers may discover traces of this feature, which will help to remove the obscurity now overhanging the relations of the Panjál rocks to the central gneiss.

To the north of the Chínáb valley in the neighbourhood of Triloknáth the Panjál rocks gradually become micaceous and thus pass downwards into foliated, and then into granitoid gneiss.

As already mentioned in the last chapter, the irregularly ellipsoidal mass of crystalline rocks marked on the map to the north-east of Triloknáth consists almost entirely of granitoid gneiss, but the junction between this and the Panjál rocks has not been fully observed. It is almost certain that this granitoid rock represents the central gneiss, and is probably in part of intrusive origin: the intrusive portion would seem to have extended through the whole of such portion of the central gneiss as now remains.

Reviewing the metamorphic rocks of the Zánskár range as a whole, it seems clear that at the north-western termination of their area these rocks include representatives of the whole of the Panjál series. On either side, towards the south-east, the metamorphism of the Panjál rocks diminishes, and in the Kishtwár and Pángi districts only the lower portions of this system have been affected by metamorphic action. The relative degree of metamorphism of the central gneiss seems to vary equally with that of the Panjál rocks,

probably depending upon the amount of igneous rock which has been intruded into it. With the exception of the very marked instances near the Bhot-kol pass, no observable traces of the unconformity which must almost certainly exist between the Panjal rocks and the central gneiss have been detected anywhere in this area. With these inconstant elements to deal with, it has been found generally impossible to draw any defined boundary between the Panjál rocks and the central gneiss, and the lines on the map, in place of being regarded as the boundaries between these two geological systems, indicate merely an almost arbitrary division between the metamorphic and the non-metamorphic rocks. It is highly probable that in the heart of the range the greater portion of the crystalline rocks belong to the central gneiss, although it is quite possible that the metamorphosed Panjáls may also be represented.

Khágán and Baltistán.

The next area in which the crystalline rocks have to be considered is Baltistán and the adjacent districts, where, as will be seen from the map, these rocks attain an enormous development, and are continued to the south-east through upper and central Ladákh. It will be found most convenient to commence the consideration of these rocks at the extreme western point of the area forming the subject of the present memoir, in the lower part of the British district of Khágán. In that district a mass of granitoid gneiss is shown as occurring to the westward of Bálákot. This rock has an extensive development to the westward, in the district of Hazára, where it has been mapped and described by Mr. A. B. Wynne, under the name of the Hazára gneiss.[1] It is described as "a completely crystalline granitoid rock, of whitish-grey colour, composed

1 "Records," Vol. XII., p. 118, and map.

of quartz, felspar, and black mica (biotite), white mica (muscovite) being often present as an accessory; and the rock is rendered porphyritic by an abundance of large twin crystals of pinkish or flesh-coloured orthoclase, measuring from two to eight inches in height, more commonly from three to four inches being the longest dimensions. Schorl [tourmaline] is locally present, and garnets are occasionally seen, both as rather unfrequent accessories. Separate veins or bands of rock-crystal or opaque quartz are rare, but dykes of easily decomposing trap, apparently greenstone, are not unusual.

"I have often sought near the junction of the crystalline rock with the adjacent schists for evidence as to its being intrusive or otherwise, and in some directions I have found what appeared to be distinct dykes or veins among the schistose rocks; but contrasting with these, and sometimes in contiguous localities, the schists exhibit a gradual alteration towards the main granitoid mass by reason of great intensity of metamorphism, the region of actual contact being, however, defined within rather narrow limits.

"For instance on the southern side of the Susul Gali pass into Agror, I found masses of the adjoining *schists included in the crystalline gneiss*, presenting many gradations of alteration; and although the stratification was still discernable, parts were as crystalline as the adjacent gneiss, enclosing the same large felspar crystals, and other parts had assumed the form of a gneiss of much finer grain than that of the main mass.

"In other cases, as near Mánsahra [Mansera], detached masses of the schistose rocks were found entangled and enveloped amidst the gneiss without exhibiting this extreme amount of alteration, not being indeed more altered than the rest of the adjacent schistose beds."

On the same page Mr. Wynne remarks that the Hazára gneiss cannot be distinguished from the porphyritic granitoid rocks of the Pír-Panjál range; and there is, indeed, no doubt that the two are the same, and, with the proviso mentioned above, belong to the central gneiss.

The schistose rocks in contact with the granitoid gneiss to the west of Bálákot (coloured purple [m] on the accompanying map) appear to underlie the latter, and the series must accordingly be inverted, as appears so frequently to be the case in the neighbourhood of large masses of granitoid or trappean rocks. According to the observations of the present writer, these schistose rocks to the southward appear to pass into the so-called Attock slates of northern Hazára, which in the main correspond to the Panjál system; and in upper Khágán are overlain by the probable representatives of the Zánskár system: these rocks must, therefore, in the main correspond to the Panjál system.

It appears, therefore, that in lower Khágán the great mass of the schistose rocks corresponds to the Panjál system, and that they are underlain by a porphyritic rock corresponding to the granitoid portion of the central gneiss. This porphyritic rock appears to be, at least in part, of igneous origin, and to have invaded and penetrated the lower portion of the schists, which correspond at least in part to the Panjál rocks. Whether, however, any of the lower portion of the schistose rocks corresponds to the original foliated central gneiss, or whether the whole of the latter formation has been absorbed by the porphyritic intrusion cannot probably be ever determined. Upon this point depends the date of the intrusion of the porphyritic rock, but judging from the Dalhousie section, it is quite likely that this may have been subsequent to the deposition of the Panjál rocks.

The schistose rocks, corresponding, at all events in the main, to the Panjál system, continue a long distance up the Khágán valley, in the higher and eastern parts of which they overlie crystalline rocks, occasionally granitoid and porphyritic, like those of Hazára, but more generally fine-grained. The junction between these two rock-systems is somewhat sudden, and there are some signs of unconformity. The granitoid rock undoubtedly corresponds to the central gneiss, and if the junction between this and the schistose rocks is an unconformable one, it would seem probable that in this district much of such portion of the central gneiss as is of igneous origin, was erupted and denuded before the deposition of the Panjál rocks; this is perhaps confirmed by the preponderance of the non-porphyritic over the porphyritic portions.

Since in the Khágán valley the junction between the schistose and the granitoid rocks is a well-marked one, it has been found possible to distinguish these two rocks on the map, and a similar distinction has been made in the lower Kishanganga valley. Although representatives of both these rock-systems occur in the districts to the eastward, it has not been found practicable to define their boundaries on the map. Consequently the north-eastern termination of the purple (m) area in the Kishanganga valley must not be regarded as a real geological boundary.

In the Kishanganga valley in the neighbourhood of Shárdi the schists consist of mica-schists or foliated gneiss, varying in their degree of crystallization till they pass into scarcely altered slates; many of the schists are garnetiferous, and occasional bands of granitoid gneiss occur. From the position of these schists beneath the metamorphosed Zánskár rocks of Changa, described in an earlier chapter, there is no doubt that they belong in the main to the Panjál system.

To the north-east of Shárdi the schists are underlain by a highly crystalline and frequently granitoid rock, which is apparently the same as the granitic pebbles found in the Panjál conglomerate higher up the river: this rock, therefore, probably belongs to the central gneiss. Higher up the river the granitoid rock is underlain by schistose rocks, a relation which is very probably due to inversion.

At the mouth of the valley of the large stream flowing from the northward into the Kishanganga between the Kankatori and Fulmai streams, and known as the Brai valley, there occurs a large development of so-called "eyed-" or "augen-gneiss": this is a foliated rock, frequently garnetiferous, and with the white felspar crystals of a peculiar lenticular form. Higher up the same valley the augen-gneiss is overlain by less completely crystalline schists, which in their turn are overlain by the metamorphosed Zánskár rocks of the head of the valley. The higher schists must accordingly clearly correspond to the Panjál system, but it is not improbable that the augen-gneiss may belong to the central gneiss.

The rocks higher up the Brai stream, on the flanks of Nanga-Parbat, appear to consist in great part of granitoid rocks probably belonging to the central gneiss.

The crystalline rocks of Baltistán, which are continuous with those noticed above, may be best considered, by describing the sections met with on the main roads. On the Gurez and Gilgit road the Panjál rocks to the south of the Dorikun pass become inferiorly more and more micaceous till they pass into a dark foliated gneiss, underlain by a light-coloured massive rock indistinguishable from true granite. The latter, which is never porphyritic, may be considered as pretty certainly belonging to the central gneiss, though the age of the overlying foliated beds is doubtful. From the occurrence of

granitoid pebbles in the Panjál rocks to the south it may be inferred that the granitoid central gneiss (probably formed, as in the case of the Dhauladhár, by the intrusion of a granitic rock into a foliated gneiss) existed as such at the time of the deposition of the Panjál rock.

The granitoid rock forms the crest of the Dorikun pass, but on the northern side it is overlain by beds of foliated gneiss and other schists. The latter continue for some distance towards the north, but at and near the village of Dás (Dárs) the lowest exposed stratum is a light-coloured granitoid rock, with large porphyritic crystals of white, or pinkish, orthoclase. This rock is the same as the Hazára and Káj-nág crystallines, and must accordingly be considered as the central gneiss: it has not been observed, however, whether this rock shows any signs of intrusion into the adjacent schists. Below Dás the rocks are generally fine-grained and dark-coloured gneissose schists, with some beds of but little altered slates: it is not easy to determine the serial relation of these rocks to the porphyritic granitoid rock, but they probably overlie the latter, and belong, at least in part, to the Panjál system.

In the neighbourhood of Astor the lowest exposed rocks (well seen near the village of Dashkin) consist of a light-coloured foliated gneiss and mica-schists: the gneiss is frequently the so-called "augen-gneiss," already mentioned. The whole of the lower part of the metamorphic rocks exposed in this neighbourhood weathers to a rusty-brown colour, is frequently highly ferruginous, and generally traversed by numerous veins of light-coloured intrusive (? oligoclase) granite. Petrologically the rocks are generally micaceous, though they are at times hornblendic, and large crystals of hornblende are not unfrequently found in the micaceous varieties. The higher portion of

the Astor crystalline series, well exhibited near Astor itself, generally consists of a dark-grey granitoid gneiss, either hornblendic or micaceous: this dark rock is quite distinct from the light-grey granitoid gneiss of the Dorikun pass. The Astor rocks, according to information afforded by Colonel H. C. B. Tanner and Dr. Scully, appear to extend over the whole of the Gilgit district.

To the north-east of Astor on the road across the Harpo pass to Rondu on the Indus, the higher dark-grey granitoid gneiss of Astor continues for some distance, and is then underlain by micaceous, and garnetiferous imperfectly crystalline schists, containing ferruginous patches weathering to a bright red or orange colour, and traversed by ramifying veins of intrusive granite. These rocks are the same as those underlying the dark granitoid gneiss of Astor, and are themselves underlain by a light-grey granitoid, and sometimes porphyritic, gneiss, corresponding to the granitoid gneiss of the Dorikun pass, and forming the core of the ridge dividing the Astor valley from the Indus valley to the north. The augen-gneiss of Astor was not observed in this section.

The core of granitoid gneiss of the Harpo pass may be considered as belonging to the central gneiss. Whether any of the schistose rocks in the neighbourhood belong to the same system cannot be determined with any certainty. Seeing, however, that the Astor augen-gneiss does not appear to be represented in the Harpo pass section, while near Astor the rocks underlying the higher dark granitoid gneiss appear to be considerably thicker than the rocks between the same and the granitoid central gneiss of the Harpo pass, it does not appear impossible that the lower part of the Astor gneiss may represent the higher foliated portions of the central gneiss, which had perhaps been denudated away in the neighbourhood

of the Dorikun and Harpo passes before the deposition of the Panjál rocks. This must, however, be regarded as purely conjectural, although it is to some extent confirmed by the occurrence in the Panjál conglomerates south of the Dorikun pass of pebbles of crystalline rocks apparently indistinguishable from some of the lower Astor rocks.

In the valley of the Indus at Rondu, to the north of the axis of the granitoid central gneiss, the rocks consist of numerous varieties of foliated and granitoid gneiss, either micaceous, or hornblendic. The intrusions of granite in ramifying veins are here extremely numerous, and belong to at least two epochs, the veins of one intrusion being traversed by those of the other. The biotite in these veins frequently occurs in crystals of very large size. At Rondu itself there is a dark-grey granitoid gneiss, apparently the same as the similar rock of Astor. Somewhat higher up the Indus valley this rock is underlain by foliated gneiss and other schists, alternating with several bands of a pure white, highly crystalline, metamorphic limestone; the whole series having an inclination of about 70° to the north-west. Still higher up the river, near its great southward bend, these schistose rocks are again underlain by a massive light-grey granitoid rock, like that of the Dorikun pass, and doubtless corresponding to the granitoid portion of the central gneiss. This granitoid rock still retains traces of its original bedding-planes, and also exhibits signs of intrusion into the overlying schists, of which it has apparently here and there caught up and included irregular fragments. Whether, however, the immediately overlying schists belong to the central gneiss, or are altered Panjál rocks, cannot be determined. The granitoid central gneiss forms an anticlinal axis, and is overlain to the south by schists and metamorphic limestones, like those on its northern side. The limestone on the southern side occurs, however,

in a single band of some three hundred feet in thickness, and contains a few imperfectly crystalline beds. Near Básho these rocks are overlain by a dark-grey granitoid gneiss, apparently the same as the higher gneiss of Astor and Rondu; a considerable thickness of schistose rocks intervening between this and the metamorphic limestones. Between Básho and Katsúra there are numerous alternations of schistose and granitoid gneiss, some of the former apparently passing into the characteristic unaltered Panjál rocks south of Skárdu.

In the Indus and Sháyok valleys above Skárdu there are very similar alternations of foliated and granitoid gneiss and other crystalline rocks, which, without doubt, contain representatives both of the central gneiss and of the Panjál system. It is, however, almost impossible to arrive at any satisfactory conclusion as to the particular age of the different divisions of the series. At Kiris, on the Sháyok, there occurs on the left bank of the river a large development of slaty rocks, like those to the south of Skárdu, which are almost certainly the representatives of the Panjál system, apparently overlain by a granitoid gneiss like that of the Dorikun pass: the whole series is, therefore, probably inverted at this spot. On the Indus the crystalline rocks, which are to a great extent of a granitoid nature, have been traced into connection with the similar rocks of Kargil and Ladákh, which will be more fully alluded to in the sequel.

On the lower Sháyok the gneiss is frequently hornblendic, and locally has veins of serpentine, and amethystine quartz with garnets. Between Skárdu and Shigar, and again at Muchilu, and at some other places in the district, the gneiss is granitoid and porphyritic, like that of Hazára and the Káj-nág, and may, therefore, be safely referred to the central gneiss. In the neighbourhood of Skárdu and

for a long distance up the Sháyok valley the crystalline rocks are in many places traversed by numerous dykes of dark minette,—an intrusive rock probably allied to mica-syenite[1]; in hand specimens this rock appears indistinguishable from the minette of Seifersdorf, in Saxony. The intrusions of the minette are remarkably well exhibited where they traverse the light-coloured granitoid gneiss between the villages of Kuru and Kurphak, on the Sháyok: some of these intrusions occur in the form of thick, irregular masses, and others in fine ramifying veins. In addition to the minette there are also numerous intrusive veins of granite, generally consisting of a finely crystalline mixture of quartz and (? oligoclase) felspar. The intrusions of the two igneous rocks appear to have taken place at several epochs, since the veins of the granite sometimes intersect those of the minette, and *vice versâ*.

In the Hushe valley, leading from the lofty Masherbrum peak (25,676 feet) into the Sháyok valley, the lowest rocks consist of the porphyritic and granitoid central gneiss, forming the higher ridges and peaks, and overlain by foliated gneiss and other schists, among which occur some of the crystalline limestones of Rondu. The granitoid rocks appear largely developed in the mountains to the eastward, drained by the Saltoro river.

Turning to the rocks of the Shigar river, flowing from the north into the Indus at Skárdu, it will be remembered that in an earlier chapter a great thickness of the metamorphosed representatives of the Zánskár system has been described as resting upon the gneissic rocks. In the Skoro ravine the lowest beds of the Zánskár rocks were described as consisting of a hard greenish slate, gradually passing downwards into a thin band of similarly coloured gneiss.

1 See F. Rutley, "The Study of Rocks," London, 1874, pp. 219-21.

Beneath the latter there occurs the following series of rocks, *viz.* :—

1. Granitoid gneiss	(about)	150 Feet.
2. Little altered blue limestones and brown sandstones greatly hardened and contorted	,,	500 ,,
3. Alternations of white metamorphic limestone with dark foliated gneiss	,,	1,000 ,,
4. Granitoid gneiss		?

The rocks marked No. 2 in this section seem almost certainly to correspond to the gneiss with bands of metamorphic limestone at Rondu; and there is some indication of the unconformity of all the metamorphic and crystalline rocks to the Zánskár rocks. Unless some such unconformity exist it is very difficult to bring the Shigar and Rondu sections into harmony; for in the latter district, as already noticed, the bands of metamorphic limestone are overlain by a great thickness of gneissose rocks, which it is almost impossible to think can be the equivalents of the Zánskár rocks of the Shigar district. This view is strongly confirmed by the position of the Zánskár rocks of Muchilu, which are in direct contact with the porphyritic central gneiss; and also by the circumstance that to the north-east of Shigar the Zánskár rocks apparently overlie granitoid gneiss. It must, however, be observed that some of the thin bands of metamorphic limestone in the Zánskár rocks of Shigar are absolutely indistinguishable from the metamorphic limestones of Rondu. Limestones, however, of any age if submitted to metamorphic action, would necessarily assume very similar characters. If the above view as to the relations of the Shigar rocks be at all correct, it will follow that on this side of the great mountain barrier separating the basin of the Indus from the basin of the Jhelam and its affluents, there must have been a break after the deposition of some of the Panjál rocks, and that these must have been largely denuded before the Zánskár rocks were laid down upon them.

Apparently the only other explanation of the relations of the Shigar rocks is to assume that the Zánskár rocks follow the underlying rocks in conformable sequence. On this view the foliated gneiss and other schists above the metamorphic limestones of Rondu would belong to the Zánskár system. Against this view there are the relations of the Zánskár rocks of Muchilu and the north-east of Shigar to the granitoid central gneiss, already mentioned. There is, moreover, the fact that the upper part of the metamorphic rocks of Rondu is so totally unlike the Zánskár rocks that, as already said, it is almost impossible to believe that they can be the same. As a third objection it may be added that there would not be a sufficient thickness of strata between the granitoid central gneiss of Rondu and the highest gneiss in that section for the occurrence of the whole series of rocks from the central gneiss to the supra-Kuling series. Finally, since the gneiss of Rondu is apparently the same as that of Astor, and since in the latter there is no limestone at all, while in the Kishanganga valley, a little to the south of Astor, the upper Zánskár rocks consist almost entirely of calcareous strata, it is almost inconceivable that any of the Astor rocks can belong to that system.

In the upper part of the Shigar district, beyond the area of Zánskár rocks, the subjacent metamorphic rocks, which are largely penetrated by granitic veins, are extremely variable in their petrological characters; they may consist either of light-coloured foliated gneiss, mica-schist, garnet-schist, or locally of kyanite-schist. These rocks occur on either border of the area of Zánskár rocks delineated on the map, and are probably inverted on the north-eastern side of the latter. The gneiss which occurs among them is very generally light-coloured, frequently distinctly foliated, very seldom granitoid, and never porphyritic. In many parts of the district the sequence of the rocks

is far from clear, but on the upper Bráldu river a very unmistakable section presents itself. In that valley, from a short distance to the westward of Hoto to some little distance to the eastward of Askole, there is a regular ascending series of these metamorphic rocks, with a few flexures, but having in general a steady easterly dip of about 45°. One or two thin bands of crystalline limestone occur among the schists, and at Askole the hard white foliated gneiss is thickly crowded with blood-red garnets: these rocks are followed by crumbly kyanite-schists, underlying the supra-Kuling rocks which have already been described.

On the eastern side of the supra-Kuling rocks a certain thickness of the above-mentioned schistose rocks occurs, and is interpenetrated by numerous granitic veins. At the terminations of the Baltoro and Palma (Punmah) glaciers these rocks are in contact with the granitoid, and frequently porphyritic, central gneiss, which seems to form the whole of this part of the great Mustágh, or Kárákoram, range, and the enormous peak of the second highest known mountain in the world (K2.=28,265 feet). The granitoid gneiss of this district is the same as the lowest gneiss of Rondu, the Dorikun pass, and the other districts in which it has been already described.

In the region under consideration it is a matter of extreme difficulty to determine the precise relationship of the schists in immediate connection with the supra-Kuling rocks to the granitoid central gneiss of the Mustágh. It seems, however, that the schistose rocks on the east of the supra-Kuling area are much thinner than those on the west, where there is a great thickness of rocks which do not belong to the granitoid central gneiss. Near the Palma glacier the schistose beds are seen dipping at a high angle towards the granitoid rocks, but it is tolerably evident that this relation must be due to inversion.

With regard to the geological age of the schistose rocks underlying the rocks of the supra-Kuling series in Bráldu, it seems evident that at least a moiety of those rocks must be the representatives of the Kuling rocks of Shigar, and it appears indeed, although the section is not very clear, that to the south-east of Askole some of the schists pass horizontally into the shales of Shigar. In western Bráldu it is extremely uncertain how much of the schist series is conformable to the supra-Kuling series, although a considerable thickness of it is undoubtedly so; there are, however, some signs of unconformity to the north of Foljo, where the schists below the supra-Kuling rocks rest upon a more massive and semi-granitoid gneiss, which, however, is not the same as the granitoid rocks of the Mustágh range, but probably corresponds to some part of the Panjál system. From this dissimilarity in the characters of the gneiss on the two sides of the supra-Kuling and subjacent schistose rocks of Bráldu, and from the fact of the central gneiss on the east being comparatively so closely placed to the supra-Kuling rocks, there is great probability of some unconformity existing on that side, and there is accordingly a strong presumption of the existence of a similar unconformity on the western side. If this view be correct (and it accords with the view taken of the Shigar section), it is not improbable that in western Bráldu the upper portion of the Panjál rocks has been denuded away, and the supra-Kuling rocks, with the associated subjacent schists, deposited on the lower part of the Panjál system; corresponding to the schists below the Kuling series of Shigar: in eastern Bráldu, on the other hand, the same rocks have been deposited on the granitoid central gneiss. It is, however, quite possible that in the later district the lower part of the Panjál system was never deposited, but that the granitoid gneiss of the Mustágh range existed as land until the time when the supra-Kuling rocks

and their subjacent schists were laid down upon it. In this case there would be no evidence for the existence of any unconformity in western Bráldu, and the whole series might consequently be in conformable sequence. The view taken above of the relations of the rocks in the Shigar section is, however, against the latter view.

On the south-western bank of the Shigar river the rocks mainly consist of more or less perfectly granitoid gneiss; at least some portion of which belongs in all probability to the central gneiss. It is probable that this valley marks the line of an extensive fault.

The notice of the metamorphic rocks of Baltistán may be concluded by a description of those met with on the route from Skárdu to Drás, across the plateau of Deosai. To the south of the Burji pass the Panjál rocks of Skárdu are underlain by the characteristic light-grey granitoid, and frequently porphyritic, central gneiss. The junction between the two rock-series appears to be an abrupt one, without any sign of the intrusion of the crystallines into the overlying rocks; leading to the inference that the Panjál rocks in this district were deposited upon an extensively eroded surface of the granitoid portion of the central gneiss, and that subsequent metamorphic action has not obliterated the original junction. This conclusion is confirmed by the occurrence in the slates of pebbles of the granitoid rock. The latter forms the foundation of the greater part of Deosai, and is overlain by patches of the Panjál rocks. On the Shingo river, draining the southern portion of Deosai, the crystallines continue in a south-easterly direction to the south of Drás: they are overlain to the south by the Panjál rocks of the Kishanganga valley; while to the north there is a narrow strip of the same rocks, passing to the south-east into the hornblendic schists of Tashgám. On the Shingo river, and in the neighbourhood of Drás, the junction between

the Panjál and the metamorphic rocks is a gradual one, probably indicating that at the deposition of the former the central gneiss had not been so extensively eroded as on the Deosai plateau, and that subsequent metamorphic action has to a great extent obliterated the distinction between the central gneiss and the overlying Panjál rocks.

At Drás the granitoid central gneiss is sometimes porphyritic, and is composed of quartz, biotite, and one or two kinds of felspar; hornblende being apparently, at all events in many instances, absent. The importance of the latter observation will be alluded to in the sequel.

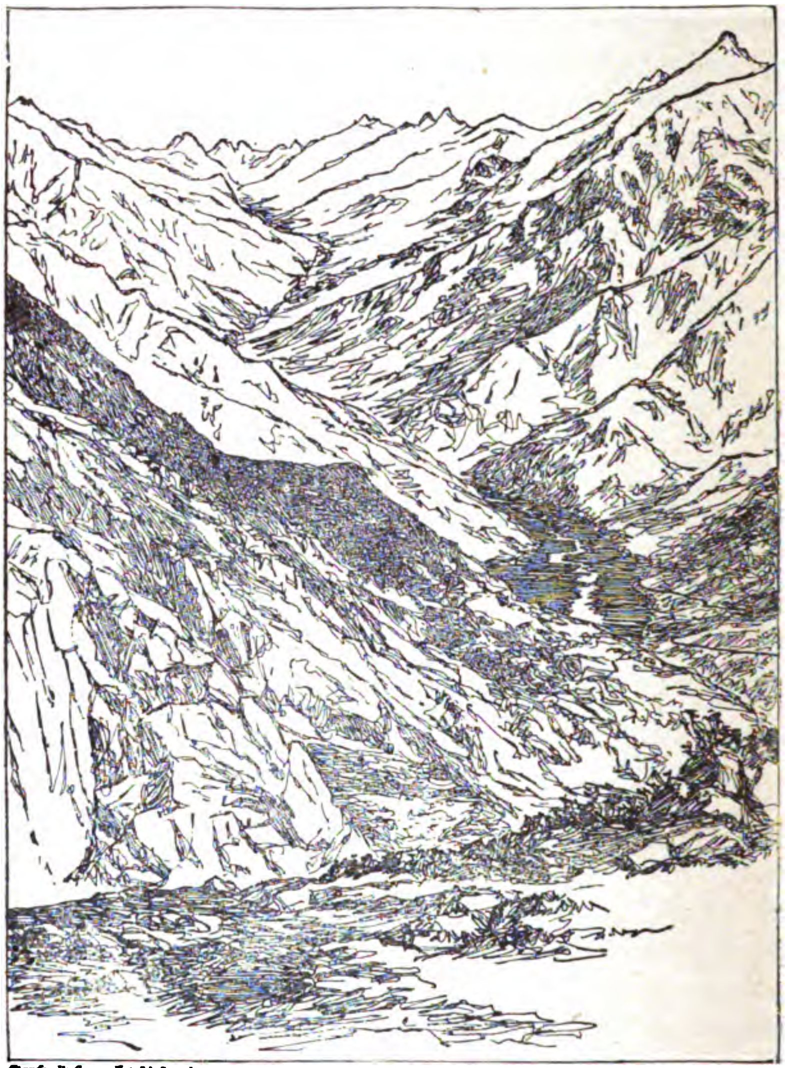
Summarizing the results of the foregoing observations of the metamorphic rocks of Khágán and Baltistán, it appears that the basement rock always consists of a granitoid, and frequently porphyritic rock, which is the same as the granitoid portion of the typical central gneiss. In some cases this rock is overlain by a great thickness of schists, the topmost beds of which correspond to the Kuling series. In these cases there is generally evidence that the topmost beds of the granitoid rock have intruded upon the lower schists. With regard to the age of the latter it is evident that a great portion of them must represent the Panjál rocks of the Káshmír valley, but it is at present impossible to say whether their lower beds may not correspond to the foliated portion of the typical central gneiss. In other instances the junction between the granitoid central gneiss is sudden, and the overlying rocks certainly belong to the Panjál system; from which it is inferred that some of the igneous portion of the granitoid central gneiss is here of earlier date than the latter. Indications of considerable breaks in the deposition of the Panjál rocks of northern Baltistán are apparent,

but the present state of information is not sufficiently ample to indicate the exact nature of these breaks. The enormous difference in the upward extent of the metamorphism which has affected the rocks of the Káshmír valley and Baltistán is a very remarkable feature, and one which may eventually lead to important conclusions as to the origin of the Himalaya.

Ladákh.

In the preceding paragraphs it has been shown that the granitoid rock of Drás is in all probability the representative of the granitoid portion of the central gneiss. The same rock occurs at Kargil, and may be traced to the north-west into connection with the crystallines of Drás. At Kargil the massive light-grey granitoid rock, without any trace of stratification, underlies a darker foliated gneiss. The view on the next page (fig. 10) of the Karkit valley, a tributary of the Suru river, to the north-west of Kargil, conveys a good idea of the barren nature of the granitoid mountains of this district. The whole sides of the valley are naked, but a narrow strip of irrigated and cultivated ground occupies the bottom.

From Kargil the southern boundary of the crystalline series runs in a south-easterly direction: it keeps to the south of the Indus till near the village of Dorgu, when it crosses to the northern side. To the eastward of the latter place the boundary forms a sinuous line along the bed of the Indus for a short distance, and then runs at some distance to the north of the river, passing close to the villages of Skining, Himis-Shukpa, and Tháru, and thence trending to the south-east till it again touches the Indus at Pitak, south of Leh. To the south-east of Pitak this boundary approximately follows the course of the Indus, but generally running somewhat to the north, and has been traced in this direction as fai as a point due south of the Pangúr lake.



Stanford's Geogl. Estabt. London.

Fig. 10.—The Karkit valley, north-west of Kargil, from the opposite bank.

Along the whole of this boundary, from Kargil to south of the Pangúr lake, the dip of the crystalline rocks is steadily to the north-east, so that the older beds are exposed along the boundary, and the newer towards the crest of the Ladákh range. The lower beds are almost invariably of the light-coloured granitoid rock; and the whole series at a little distance shows a distinctly stratified appearance, although in hand specimens many of the rocks are indistinguishable from granite.

According to the description of Dr. Stoliczka[1] these rocks in the neighbourhood of Leh consist in great part of a "moderately fine-grained syenite, crossed by veins which are somewhat richer in hornblende, while other portions contain a large quantity of schorl [tourmaline]. Both about Leh and further eastward beds of dark, almost black, fine-grained syenite occur in the other rock. The felspar often almost entirely disappears from this fine-grained variety, and quartz remains very sparingly disseminated, so that gradually the rock passes into a hornblendic schist; and when schorl replaces hornblende, the same rock changes into layers which are almost entirely composed of needles of schorl. Again, the syenite loses in places all its crystals of hornblende, the crystals of felspar increase in size, biotite (or sometimes chlorite) becomes more or less abundant, and with the addition of quartz we have before us a typical gneiss (or protogine gneiss), without being able to draw a boundary between it and typical syenite. However, the gneissic portions, many of which appear to be regularly bedded, are decidedly subordinate to the syenitic ones. As already mentioned, the rock often has a porphyritic structure, and the felspar becomes pink, instead of white,—as, for instance, on the top of the Khardung [Khardong] pass and on the

1 "Scientific Results of Second Yarkand Mission.—Geology," pp. 15-16.

southern slope of the Cháng-la,[1] where large fragments are often met with without the slightest trace of hornblende." Dr. Stoliczka then describes the partially metamorphosed Panjál rocks of the Tánktse district as overlying the syenitic and other gneissic rocks. It is concluded that these rocks correspond to the silurian, but it does not appear quite clear whether this determination was intended to include the whole of the crystalline rocks of the Ladákh range.

It will be unnecessary to describe the northern limits of the Ladákh crystallines, as this is sufficiently indicated on the map, which also exhibits their connection with the crystallines of Baltistán. At Tánktse (forty miles to the eastward of Leh) the greater portion of the gneiss is a light-coloured granitoid porphyritic rock, generally without hornblende,[2] and apparently the same as the typical granitoid central gneiss; the higher beds frequently consist of alternations of dark and light bands. This porphyritic rock forms the whole of the core of the range running from Tánktse in a south-easterly direction; and while at the latter place the porphyritic crystals of orthoclase are pure white in colour, at Chushál (forty-five miles to the south-east) they are of a decided pink tint, and frequently attain a very large size. The porphyritic rock is distinctly overlain by the Panjál rocks on either side of the range. On the northern flanks of the Tánktse range, to the north-east of Tánktse itself, there is a regular ascending series of gneissic rocks, with a north-easterly dip. The higher beds become gradually interstratified with unaltered slates and sandstones, and some banded jaspideous rocks, till finally all gneiss disappears. The foliated gneissic rocks between Muglib and Sháyok,

1 This pass is not marked on the accompanying map; it is situate on the ridge between Sákti and Tánktse.

2 It has been stated that the gneiss is syenitic, but this is not generally the case.

overlying the granitoid rocks of Tánktse, and apparently passing into the Panjál rocks of the south-eastern side of the Pángkong lake, are almost certainly the altered equivalents of the latter, and accordingly have been so coloured (m) on the map. It must not, however, be assumed from this that there are no other altered equivalents of the Panjál rocks in this neighbourhood.

The anticlinal of crystalline rocks occurring on the road from Tánktse to Chángchenmo, which is crossed at the Másimik pass, and to the north-west is apparently in connection with the Tánktse crystallines, consists in its higher beds of alternations of lighter and darker beds, some of the latter being garnetiferous. On the crest of the pass the central core of the gneiss is usually a porphyritic granitoid rock, like that of Tánktse. The transition from the crystalline rocks of the Másemik-lá to the overlying Panjál rocks is an imperceptible one. This anticline of crystalline rocks appears to continue to the south-east to the borders of Káshmír territory.

In the Chimre (Chimray) valley (leading from the range south of Tánktse to the Indus) the crystalline rocks, which consist of alternations of a light-coloured granitoid rock, with darker foliated bands, are traversed in all directions by veins of intrusive oligoclase granite. The biotite in the latter occurs in very large plates, and not unfrequently forms a coating to large crystals of quartz.

As already mentioned, it is somewhat uncertain how much of the crystalline rocks of Ladákh was considered by Dr. Stoliczka as corresponding to the silurian (Panjál) system, although it is probable that at least a large portion of them was so classed. It appears, however, from the identity of the granitoid gneiss of Kargil with that of Drás, from the relations of the lower crystallines of Leh and Tánktse to the overlying Panjál rocks, and also from

the apparent identity of the porphyritic granitoid rock of Tánktse and Chushál with the typical granitoid central gneiss of other regions, to be practically certain that at least a very considerable portion of the crystalline rocks of Ladákh must correspond to the central gneiss. How much of these rocks belong to this system, or to what extent they are of igneous and to what extent they are of metamorphic origin cannot, however, be yet determined. The resemblance of the granitoid porphyritic rock of Tánktse to the intrusive porphyritic rock of other regions leads, however, to the conclusion that this rock is probably of igneous origin, although the date of its eruption cannot yet be determined. That many of the fine-grained granitoid rocks of the northern side of the Indus valley are likewise at least in part of igneous origin is also highly probable, but the very distinctly marked stratification which they still retain points to the conclusion that such elements of igneous origin as they may possess must have been intruded among an originally foliated rock, the distinctive marks of which were not entirely swept away by the intrusion. It is difficult to point to any of the Ladákh crystallines, except those to the north-east of Tánktse, which may with probability be considered as the representatives of the Panjál system, but perhaps the most likely are the higher banded beds overlying the granitoid rocks of Kargil.

The conclusion that a very large portion of the Ladákh crystallines probably corresponds to the central gneiss is very strongly confirmed by the fact that in the neighbourhood of Lámayúru the entirely unaltered representatives of the Panjál system (which are here absolutely indistinguishable from the typical rocks of the Múth and Bhábeh series) are in comparative proximity to the highly metamorphic crystallines of the Indus valley. It seems, indeed, almost inconceivable,

on the hypothesis of these two series of rocks being equivalent, that at one spot they should consist of shales and slates, without the slightest trace of alteration over a considerable area, while six miles to the south they should consist of a rock indistinguishable in hand specimens from granite.

Apparently the chief reasons why Dr. Stoliczka did not identify any of the Ladákh crystallines with his central gneiss were the presence in the former of hornblende, and the absence of the intrusive oligoclase granite. With regard to these points, it may first be recalled that Dr. Stoliczka refused to identify the crystallines of the Outer Himalaya with the central gneiss; showing that his limitation of that system is not of much value. The presence or absence of granitic veins (which are indeed present in the Chimre valley) seems to be a character of not the slightest importance. With regard to the hornblende, the purely granitoid rocks of Drás, passing on one side into the typical central gneiss of Baltistán, and on the other, through Kargil, into the syenitic rocks of the Ladákh range, seems to point unmistakeably to the conclusion that the difference in the mineralogical composition of the Ladákh, and the typical central gneiss cannot be taken as indicative of their belonging to distinct geological formations. The apparent identity existing between the porphyritic granitoid rocks of Tánktse and other parts of Káshmír territory, may possibly lead to the further conclusion that in Ladákh the composition of the foliated portions of the central gneiss and the overlying rocks was such as to induce the formation of a hornblendic rock by metamorphic action, while the later intrusions of igneous rock were often, as in other parts of the Himalaya, of sufficient acidity to cause the resulting compound rock to assume a granitic character. It should also be observed that the information regarding the foliated portion of the central gneiss in other parts of

Káshmír territory is not at present sufficiently ample to afford grounds for denying the presence of hornblendic rocks in other districts, and it has, indeed, been shown that this mineral is abundant in some of the gneiss of Astor and Rondu, although the age of those rocks cannot be precisely determined.

Rupshu.

The only remaining area where metamorphic rocks are largely developed is the district of Rupshu, where they have been described by Dr. Stoliczka.[1] According to this description the zone of Kuling rocks to the south of Tso-Moriri (Tsomoriri[2]) is underlain to the northward by "thin-bedded chloritic and micaceous schists, traversed by a great number of veins of pure white quartz. A short range of snow-covered mountains, which rise to about 21,000 feet, extends some distance to the north-west and terminates somewhat to north of the southern end of the Tsomoriri lake. This range consists of granitoid gneiss, coarsely stratified, in fragments representing good typical granite. The rock is peculiar from having the greater quantity of felspar of a pink *Orthoclas* [orthoclase], which we met here only for the second time on all our journey. The felspar and quartz are present nearly in equal quantities, and the mica is a dark brown or black biotite. I have not observed any veins of albite-[oligoclase] granite in this gneiss, neither any other accessory minerals worthy of particular attention. To the north of this granitoid ridge we have again a series of thinner stratified beds. They are principally quartzose schists, containing some felspar, and laminated biotite of a grey

1 "Memoirs," vol. V., pp. 127-8.

2 The word is spelt in this manner on the accompanying map, followed by the word 'lake,' thus contravening the rule for the employment of the Tibetan word 'Tso' (lake), as laid down on page 3. This discrepancy escaped the writer's notice until the earlier proof-sheets had passed the press: a similarly redundant term is used by Dr. Stoliczka in the passage quoted.

graphitic colour: muscovite is very subordinate and often wanting altogether. Through the felspar these schists, when occurring in somewhat thicker beds pass very easily into gneiss.

"True gneiss is again to be found in the neighbourhood of the small Gyagar [Kyágar] lake (to the north of Tsomoriri). It is apparently very different from the former, south of Korzok [Karzok, on the western side of Tso-Moriri]. The quartz is white, but impure and sandy, the mica is the same biotite, and besides smaller pieces of pure felspar, there occur large crystals of orthoclas which are very impure by admixture of white albite and mica. Veins of albite-[oligoclase] granite have equally not been observed here, but black tourmaline is to be met with in large quantities and often in large lumps. Being rather thinly stratified, the gneiss passes on the other side with very gradual changes again into quartzose beds, which are only devoid of the large crystals of felspar, but still contain schorl [tourmaline] in abundance. These quartzose schists form both sides of the Púga valley, and become towards the epidote rocks [tertiary traps] somewhat chloritic, and even garnetiferous, they dip against these epidote rocks, where they are visible in the eastern part of the Púga valley."

To the north-west the schistose beds of this metamorphic series pass insensibly into the slightly metamorphosed Panjál rocks, whose distribution is approximately indicated on the map. From this circumstance, coupled with the fact that the schists and quartzites immediately underlie the Kuling rocks of south Rupshu, it is practically certain, as Dr. Stoliczka concluded, that the Rupshu metamorphics must contain among them the representatives of the Panjál system. It is, however, highly probable that the granitoid gneiss of Karzok and Tso-Kyágar (the difference in the structure of

these rocks mentioned by Dr. Stoliczka is too slight to be of any importance) is the representative of the central gneiss, with some of the granitoid portions of which it seems to agree very closely in petrological characters. On this supposition many of the beds of the Rupshu metamorphics must be inverted, since in the Tso-Moriri district most of the beds dip to the south-west.

As showing the apparently slight importance of the mineralogical constituents of the gneissic rocks in respect to their geological age, it may be observed that while on account of the presence of hornblende Dr. Stoliczka was apparently deterred from referring any of the Ladákh crystallines to the central gneiss, yet the presence of this mineral in the latter, and its absence in the crystallines of Rupshu was apparently considered no obstacle to classing both these as representatives of the palæozoics.

Summary.

At the risk of a certain amount of repetition, it may be well to briefly epitomize some of the leading points in connection with the crystalline and metamorphic rocks.

The foregoing observations have shown that most of the pink (n) areas in the map contain representatives both of the Panjál (older palæozoic) and of the central (archæan) gneiss; while in most cases there is no means of drawing any boundary between the two. In certain instances there is clear evidence of the denudation of the latter before the deposition of the former, and it is consequently presumed that a similar unconformity, now generally obliterated by metamorphic action, must originally have existed in all cases between the two rock-systems. The central gneiss generally shows more or less distinct traces of its original sedimentary origin, but has been largely modified by enormous granitic intrusions, which

seem to have occurred at more than one epoch. The more important and bulky of these intrusions appear to have involved the, at all events partial, liquefaction of the whole mass, and do not send up long veins into the overlying rocks. Although some of these intrusions appear in certain cases to have invaded and absorbed some of the overlying Panjál rocks, and cannot, therefore, be considered as the oldest rocks, yet their presence probably implies that the original basement of the whole rock-system must exist among them, and it is, therefore, best to consider all these massive granitoid rocks as related to the archæan system. The minor and latest intrusions exist in the form of ramifying veins which preserve a tolerably uniform character in their passage through both the granitoid and the foliated rocks, and they cannot therefore be regarded as forming an integral part of the central gneiss. Considerable variation in respect of petrological characters exists among the crystalline rocks, but much of the granitoid, and more especially the porphyritic, portion of the central gneiss is very constant in this respect.

The observations recorded above indicate the enormous amount of detailed work, in connection with the classification of the crystalline and metamorphic rocks, which remains for the author's successor in the exploration of the geology of the Káshmír and adjacent territories.

CHAPTER X.—ECONOMIC GEOLOGY.

Introductory: a. SUBSTANCES USED IN THE UNCOMBINED STATE, AND THEIR ALLIES (*graphite: amber: peat: coal: sulphur: bismuth: gold: copper: iron.*) b. ALUMINUM COMPOUNDS (*sapphire: alum: turquoise.*) c. SODIUM, POTASSIUM, MAGNESIUM, AND CALCIUM COMPOUNDS (*salt: sodic carbonate: magnesic and (?) sodic sulphate: borax: saltpetre: serpentine: gypsum: limestone.*) d. SILICA (*rock-crystal.*) e. BUILDING-STONES (*trap: sandstone: granite and gneiss: limestone: slate.*) f. MISCELLANEOUS (*Mdni-stones: mill-stones: bowls: Sirínagar lapidaries.*)

Introductory.

The list of the economically useful products of the rocks of the Káshmír and Chamba states is at present extremely meagre, and, considering the size of these states, comparatively unimportant. The poverty of this list may indeed be in part due to the want of a proper system of organized exploration, but it may be also partly due to the absence of any great abundance of the precious metals, and the more valuable minerals. With regard to the former it is hardly likely that any number of rich lodes should have escaped the notice of the natives, who in general are energetic miners in cases where the precious metals can be obtained without the aid of complex machinery.

Apparently the only European who has been commissioned by the Káshmír Government to search for minerals was Mr. Drew,[1] and it would seem that his researches were not rewarded with that success which rendered it expedient that they should be continued. The present writer cannot claim to be in any way an expert in the

[1] *Vide* "Jummoo and Káshmír Territories," p. 23.

detection of metalliferous lodes, and the fact of his not meeting with such cannot consequently be regarded as of very great value. Still all the available information points towards the conclusion that the Káshmír Himalaya is not likely to be an important producer of the precious metals. An instance of the existence of large quantities of copper in one region will, however, be noticed below, and a lately discovered source of sapphire is likely to be of some commercial importance.

As in native states it is frequently considered that the sole object of a geologist is the discovery of precious minerals, and as it was particularly undesirable that this view should be entertained as to the object of the present writer's journeys in Káshmír territory, his opportunities of observing such mines and metalurgical establishments as exist were greatly limited. For this reason, and from the absence of all other important sources of information, the following list of products, in the arrangement of which a slight modification of the plan followed in the third part of the "Manual of the Geology of India" has been adopted, must be regarded as extremely imperfect. It has not been considered advisable to introduce in this list minerals like garnet, kyanite, mica, and tourmaline, which though locally abundant are not generally of any economic importance. It might, perhaps, have been expected that jade would have occurred in this list, but the sources of this mineral are in the Kárakásh river, beyond the proper limits of Káshmír territory.

a. Substances used in the uncombined state, and their allies.

Graphite.

Graphite is said by Baron Hügel to occur on the Pír-Panjál.[1]

Amber.

Amber beads are much used as ornaments by the Ladákhi women, but it is believed that the whole are imported.

1 *Vide supra*, p. 10.

Coal.

There does not appear to be the slightest probability that workable coal will ever be found in the Káshmír or Chamba territories. There are, however, in many places thin strings and nests of coaly matter which have given rise to the usual wild expectations of workable coal being found beneath the surface. In the rocks of the Murree group at Kohála on the Jhelam (lat. 34° 12', long. 73° 60'), thin strings of coal are not unfrequent on both sides of the river; and a few years ago more than a bushel was extracted on the right bank and forwarded to the Commissioner of Hazára. Similar strings occur higher up the Jhelam at Uri, and in other parts of the Murree group. In the nummulitic rocks (Subáthu group) of the Outer Hills coaly beds are of very common occurrence; and are well developed in the nummulitic inlier on the Púnch river.[1] In the Zánskár rocks of the upper Ans river (joining the Chínáb at Riási) thin strings of bright brittle coal are common, and some of the corresponding rocks of the Kashmír valley have here and there almost a coaly nature.

Peat.

It is recorded[2] that a sample of peat obtained by Dr. Falconer in Káshmír, probably from the neighbourhood of the Walar lake, yielded a percentage of 37.15 of carbon. This peat contained the remains of water-plants, but none of mosses.

Sulphur.

Specimens of native sulphur from the Káshmír valley have been shown to the present writer: they were probably obtained from the neighbourhood of the hot springs of the Víhi district.

1 In the "Manual" (pt. III., p. 102) this coal of Dandli on the Púnch is alluded to as being of far more importance than it really is.

2 See "Manual," pt. III., p. 123.

In the Púga valley of Ladákh sulphur is obtained, in company with other minerals, from the deposits of the hot springs. It is described[1] as occurring in fissures, and between the laminæ of a quartz-schist, sometimes in a massive form, but more often in small transparent crystals. Sulphur is also deposited at the surface by the same springs, It is said that in some years the product of sulphur from the Púga workings has been as much as from 500 to 600 maunds.[2]

Bismuth.

It is stated[3] that small quantities of bismuth have been obtained from the Jamu district.

Gold.

It is extremely difficult to find out to what extent the operation of washing the river sands for gold is still carried out in Káshmír territory. It is, however, tolerably certain that all these sands are more or less auriferous; and pits formed by the gold-searchers are to be found in many of the valleys, from the Outer Hills to upper Baltistán and Ladákh. At Kargil (lat. 34° 34′, long. 76° 10′ 30″), on the Suru river numbers of these pits may be observed. They are also very numerous on the Indus in the neighbourhood of Skárdu, and higher up at the village of Achínathang (lat. 34° 56′, long. 76° 75′), where they are sunk in a pebble alluvial terrace some 120 feet above the level of the river.[4] At Skiu, on the Markha river (lat. 33° 110′, long. 77° 35′), these pits occur in great numbers, and many of them are of recent excavation: the alluvium in which they are excavated appears to be in part derived from the wearing down of quartz-reefs in the neighbouring Kuling rocks.

In the Gilgit district it is reported that gold occurs in greater

1 "Memoirs," vol. V., pp. 160-3.

2 A maund properly equals 80lbs.; but the Káshmír maund is generally somewhat less.

3 See "Manual," pt. III., p. 163.

4 See "Jummoo and Káshmír Territories," p. 267.

quantities than elsewhere in the river sand and alluvial beds, but the author has no precise information on the subject.

In general the product of these alluvial gold washings, many of which are now totally abandoned, is believed to be very small, and is said only just to repay the labour expended on it even in the winter season when agricultural work is slack, or *nil*.

Copper.

Large masses of pure native copper have been found in the bed of the lower part of the Zánskár river, but their source is unknown. Several of such masses, which occurred in the form of water-worn nodules reaching to 22lbs. in weight, were in 1879 in the possession of the late Mr. W. H. Johnson, then Governor of Ladákh, by whom they were shown to the present writer. A small specimen is preserved in the Indian Museum.[1]

Copper-glance, and copper-pyrites, have been received from Rondu, in Baltistán[2]: it is also stated that copper-ore has been obtained from the upper Lidar valley.[3]

Iron.

In a breccia at the base of the inlier of the Subáthu group on the Púnch river (in the Outer Hills) iron-ore has been extensively mined. "The ore is a cellular limonite occurring in nests and strings through the breccia; it is probably derived by decomposition and infiltration from the coaly band of the Subáthu group."[4] In the inlier of the same group on the Chínáb, in the Riási district, iron is now worked in the neighbourhood of the Dragar Mountain (Dragari-Thár), to the north of Pauni.[5]

1 It is mentioned by General Cunningham ("Ladak," p. 22) that the name Zánskár, or Zángskár, is derived from *zangs*,—copper, or brass.

2 "Manual," pt. III., p. 267. 3 *Ibid.* 4 "Records," vol. IX., p. 54.

5 See "Jummoo and Káshmír Territories," pp. 137-8.